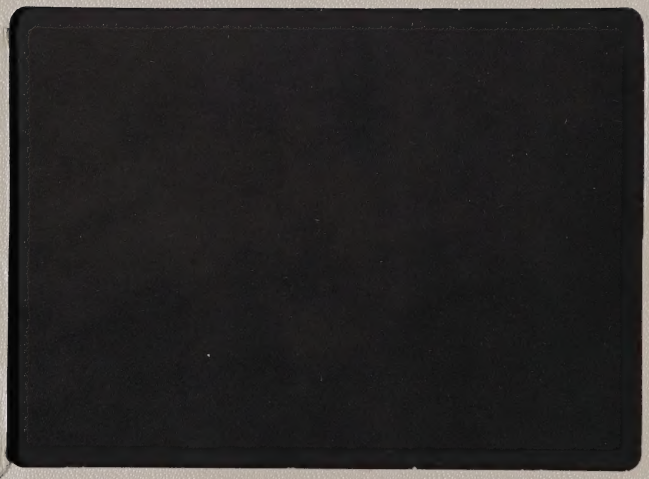
GenRad

GR 1657 Digibridge™

Form 1657-0100-A

Instruction Manual



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GR 1657 Digibridge™

Form 1657-0100-A

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Concord, Massachusetts, U.S.A. 01742
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ID-0100

Specifications

Measurement Mode: Measures R series or parallel; L and Q series or parallel; C and D series or parallel. All measurement modes are pushbutton selectable.

Displays: LED-type numerical display with automatically positioned decimal points and illumination of units. For RLC, five digits (99999) and simultaneously for DQ, four digits (9999).

Measurement Speed: Greater than 3 measurements per second.

Test frequencies: Pushbutton selection between 2. Accuracy re panel legends: +2%, −.01%. Actual frequencies: for 1657-9700, 1020.0 Hz ± .01% (panel legend "1 kHz") and 120.00 Hz ± .01%; for 1657-9800, 1000.0 and 100.00 Hz ± .01%.

Applied Voltage: 0.3 V rms maximum.

Ranges: Pushbutton selection with automatic front-panel guidance. Three basic ranges (best accuracy, see table) of 2 decades each, for each parameter. Automatic extensions to min and max, as tabulated.

Parameter	Minimum	Basic ranges	Maximum
R; 120 Hz*	ØØ.001 Ω	2 Ω to 2 MΩ	99.999 MΩ
R; 1 kHz	ØØ.001 Ω	2 Ω to 2 MΩ	9.9999 MΩ
L; 1 kHz	Ø.0001 mH	0.2 mH to 200 H	999.99 H
L; 120 Hz*	ØØ.001 mH	2 mH to 2000 H	9999.9 H
C; 1 kHz	Ø.0001 nF	0.2 nF to 200 μF	999.99 μF
C; 120 Hz*	ØØ.001 nF	2 nF to 2000 μF	99999 μF
D (with C)	.0001	(fully automatic)	9.999
Q (with L)	00.01	(fully automatic)	999.9

*120 Hz or 100 Hz, depending on the instrument.

Accuracy: For R, L, and C: ±0.2% of reading in basic ranges, if quadrature component is small (D < 0.1, Q > 10, etc). See table.
D accuracy: ±.001 in basic ranges, for D < 0.1 (otherwise, see table).
Q accuracy: ±.01 in basic ranges, for Q < 1 (otherwise, see table).

Parameter	Basic accuracy: Low extension	Basic accuracy: Basic ranges	Basic accuracy: High extension	Cross-term factor
R; either frequency	±[4 mΩ,	0.2% of rdg,	(R/10 MΩ)% of rdg	] (1 + Q)
L; 1 kHz	±[0.4 μH,	0.2% of rdg,	(L/1000 H)% of rdg	] (1 + 1/Q)
L; 120 Hz*	±[4 μH,	0.2% of rdg,	(L/10 kH)% of rdg	] (1 + 1/Q)
C; 1 kHz	±[0.4 pF**,	0.2% of rdg,	(C/1000 μF)% of rdg	] (1 + D)
C; 120 Hz*	±[4 pF**,	0.2% of rdg,	(C/.01 F)% of rdg	] (1 + D)
D (with C)	±[	.001 + 0.2 (1 + D)% of rdg		] K†
Q (with L)	±[	.01 + 0.2 (1 + Q)% of rdg		] K†

*120 Hz or 100 Hz. **Fixed offset "zero" capacitance is < 1.5 pF.
†K = (LC basic accuracy as % of rdg) / 0.2%. Therefore, K = 1 on basic ranges.

Environment: TEMPERATURE: 0 to 50°C operating, −40 to +75° C storage. HUMIDITY: 0 to 85% R.H., operating.

Supplied: Power cord, axial-lead adaptors, instruction manual.

Power: 90 to 127 V or 180 to 254 V, 48 to 62 Hz. Voltage selected by rear-panel switch. 25 W maximum.

Mechanical: Bench mounting. DIMENSIONS: (wxhxd): 375x112x343 mm (14.8x4.4x13.5 in.). WEIGHT: 5.6 kg (12.3 lb) net, 10 kg (22 lb) shipping.

Description	Catalog Number
1657 RLC Digibridge™	
120-Hz and 1-kHz Test Frequencies	**1657-9700**
100-Hz and 1-kHz Test Frequencies	**1657-9800**
Extender Cable (for remote measurements)	**1657-9600**

Patent applied for.

Warranty

GenRad

We warrant that this product is free from defects in material and workmanship and, when properly used, will perform in accordance with applicable GenRad specifications. If within one year after original shipment it is found not to meet this standard, it will be repaired or, at the option of GenRad, replaced at no charge when returned to a GenRad service facility. Changes in the product not approved by GenRad shall void this warranty. GenRad shall not be liable for any indirect, special, or consequential damages, even if notice has been given of the possibility of such damages.

THIS WARRANTY IS IN LIEU OF ALL OTHER WARRANTIES, EXPRESSED OR IMPLIED, INCLUDING, BUT NOT LIMITED TO, ANY IMPLIED WARRANTY OF MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE.

GenRad policy is to maintain product repair capability for a period of ten years after original shipment and to make this capability available at the then prevailing schedule of charges.

Introduction–Section 1

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1.1 PURPOSE.

The 1657 Digibridge ™ is a digital impedance meter embodying use of a microprocessor and other LSI circuitry to provide excellent performance at low cost.

A few clearly labeled pushbuttons and the versatile built-in test fixture make this instrument a model for convenience. Measurement results are clearly shown with decimal points and units, which are automatically presented to assure correctness. Display resolution is 5 digits for R, C, and L (4 for D or Q) and the basic accuracy is 0.2%.

Long-term accuracy and reliability are assured by the measurement system. It makes these accurate analog measurements over many decades of impedance without a single calibration or "trimming" adjustment (not even in original manufacture).

The built-in test fixture, with a pair of plug-in adaptors, receives any common component part (axial-lead or radial-lead), so easily that insertion of the DUT is a one-hand operation. True 4-terminal connections are made automatically. An extender cable is available for measurements at a distance from the instrument, typically for bulky components.

1.2 GENERAL DESCRIPTION.

Convenience is enhanced by the arrangement of test fixture on the front ledge, with pushbuttons farther forward and display behind. The display panel is inclined and recessed to enhance visbility of digital readouts and mode indicators. These indicators serve to inform and guide the operator as he operates the simple controls.

The instrument stands on a table or bench top. The sturdy metal cabinet is attractively and durably finished, in keeping with the long-life circuitry inside. Glass-epoxy circuit boards interconnect and support high-quality components to assure years of dependability.

Adaptability to any common ac power line is assured by the removable power cord and the convenient line-voltage switch. Safety is enhanced by the fused, isolating power transformer and the 3-wire power connection. A comprehensive functional description is given in Theory, Section 4. Electrical and physical characteristics are listed in Specifications at the front of this manual, dimensions in Installation, Section 2. Controls are described below, and their use in Operation, Section 3.

1.3 CONTROLS, INDICATORS, AND CONNECTORS.

Figure 1-1 shows the front panel controls and indicators. Table 1-1 identifies them with descriptions and functions. Similarly, Figure 1-2 shows the rear panel; and Table 1-2 identifies and describes the rear panel controls and connectors.

1.4 ACCESSORIES.

GenRad makes several accessories that enhance the usefulness of this instrument. The extender cable facilitates making connection to those devices and impedance standards that do not readily fit the built-in test fixture. The cable branches into 5 parts, each with a stackable banana plug, for true 4-terminal connections (and guard) to the device being measured, without appreciable reduction in measurement accuracy. Other useful accessories are offered, such as standards for checking the performance of the Digibridge. Refer to Table 1-3 and Section 5.

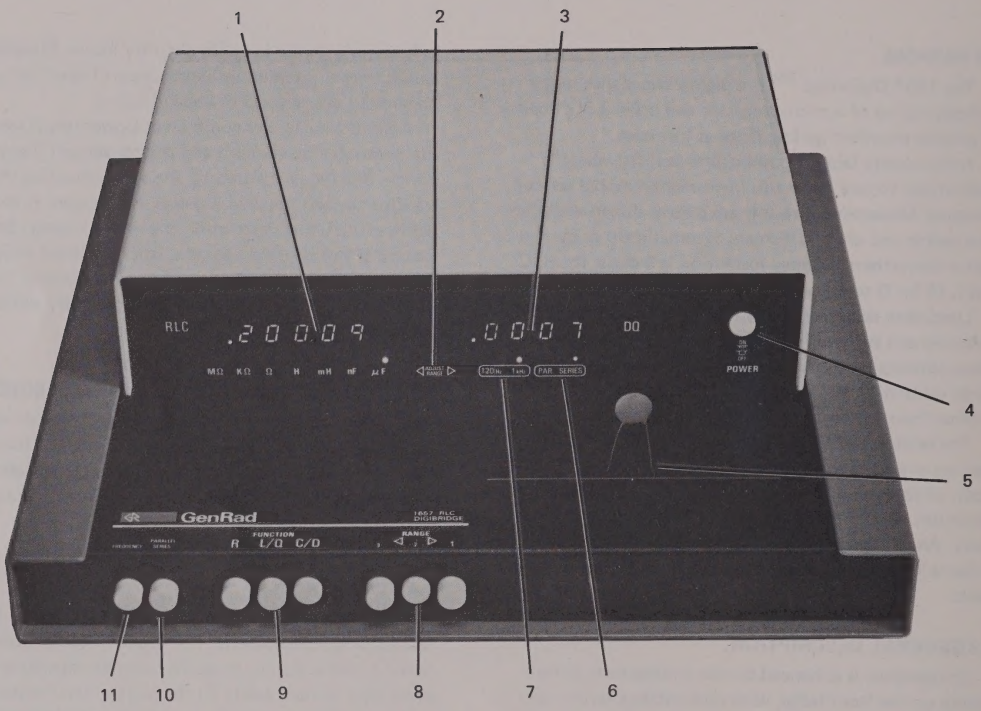

Figure 1-1. Front panel controls and displays.

Table 1-1
FRONT PANEL CONTROLS AND INDICATORS

Figure 1-1 Ref.No.	Name	Description	Function
1	RLC display	Digital display, 5 numerals with decimal points. Unit labels MΩ, kΩ, Ω, mH, nF, μF, with 7 lights.	Display of principal measured value. Light spot indicates units.
2	ADJUST RANGE lights	Arrowheads with a light behind each.	Guides operator to optimum range. Left arrow means "try next pushbutton to left." Right arrow means the converse. No light means "Correct range." Also see para 3.3.
3	DQ display	Digital display, 4 numerals with decimal points.	Display of secondary measured value, D if you select C/D, Q if you select L/Q with item 9.
4	POWER switch	Pushbutton (push again to release).	Turns instrument ON when in, OFF when out. OFF position breaks both sides of power circuit.
5	Test fixture	Pair of special connectors; each makes dual contact with inserted wire lead of DUT.	Receives radial-lead part, making 4-terminal connection automatically. Adaptors are supplied to make similar connection with axial-lead part.
6	PARALLEL/SERIES lights	Legend with 2 lights.	Indicates the selection of parallel or series equivalent circuit of the DUT (by item 10). Refer to para 3.5.
7	Frequency lights	Legend with 2 lights, 120 Hz, 1 kHz, (or 100 Hz, 1 kHz).	Indicates the selection of test frequency by item 11.
8	RANGE pushbuttons	Set of 3 interlocked, latching pushbuttons, labeled 3, 2, 1. The latched button is released by depressing another one.	Manual selection of measurement range, in conjunction with item 9.
9	FUNCTION pushbuttons	Set of 3 pushbuttons, similar to item 8, labeled R, L/Q, C/D.	Manual selection of parameter to be measured: resistance, inductance, or capacitance.
10	PARALLEL/SERIES pushbutton	Pushbutton (push again to release).	Manual selection of equivalent circuit. Item 6 indicates the one in use.*
11	FREQUENCY pushbutton	Pushbutton, like item 10.	Manual selection of frequency. Item 7 indicates the frequency in use.*

*When these buttons are "in", the selections are PARALLEL and 120 Hz (100 Hz).

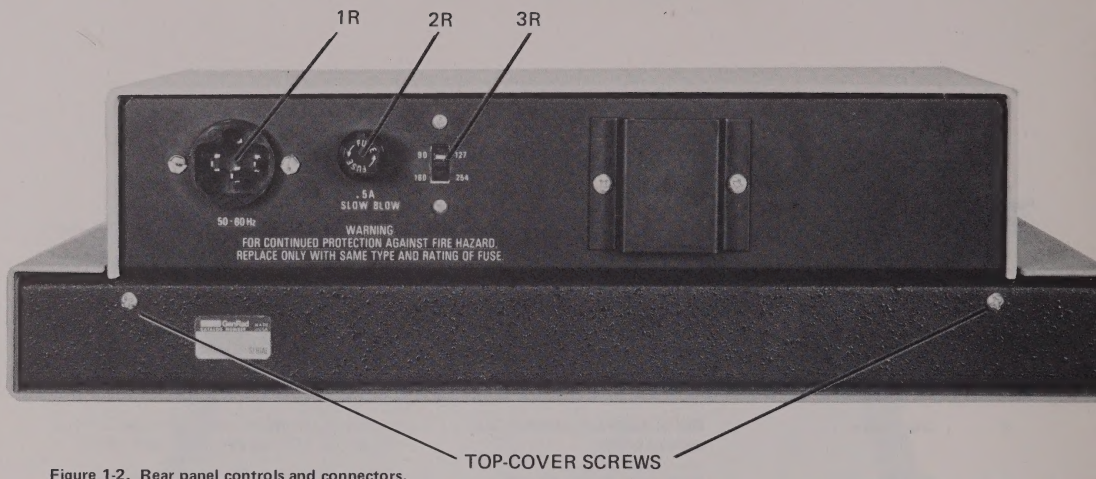

Figure 1-2. Rear panel controls and connectors.

Table 1-2

REAR PANEL CONNECTORS AND CONTROLS

Figure 1-2 Ref. No.	Name	Description	Function
1R	Power connector, (labeled 50-60 Hz)	Safety shrouded 3-wire plug, conforming to International Electrotechnical Commission 320.	Ac power input. Use appropriate power cord, such as GR 4200-9625, with Belden SPH-386 socket or equivalent.
2R	Fuse (labeled 0.5 A, SLOW BLOW)	Fuse in extraction post holder.	Short circuit protection. Use Bussman type MDL or equivalent fuse, 1/2 A rating.
3R	Line-voltage switch	Slide switch. Upper position, 90 to 127 V; lower position, 180 to 254 V.	Adapts power supply to line-voltage ranges, as indicated. To operate, use small screwdriver, not any sharp object.

Table 1-3

ACCESSORIES

Quantity	Description	Part Number
1 supplied	Power cord, 210 cm (7 ft) long, 3-wire, AWG No. 18, with molded connector bodies. One end, with Belden SPH-386 socket, fits instrument. Other end is stackable (hammerhead) conforming to ANSI standard C73.11-1966.	4200-9625
2 supplied	Test-fixture adaptors, for axial-lead parts	1686-1910
1 recommended	Extender cable for connection to multi-terminal standards and large or remote DUT's. Length 100 cm (40 in.).	1657-9600

Installation—Section 2

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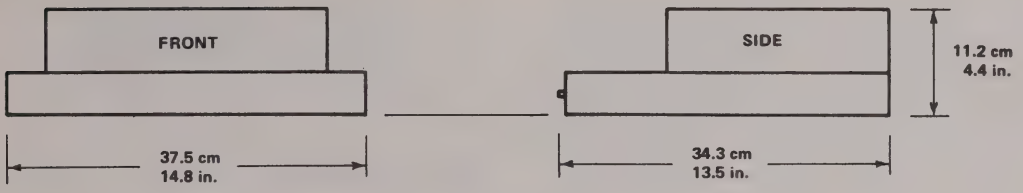

Figure 2-1. Overall dimensions.

2.1 UNPACKING AND INSPECTION.

If the shipping carton is damaged, ask that the carrier's agent be present when the instrument is unpacked. Inspect the instrument for damage (scratches, dents, broken parts, etc.). If the instrument is damaged or fails to meet specifications, notify the carrier and the nearest GenRad field office. (See list at back of this manual). Retain the shipping carton and the padding material for the carrier's inspection.

2.2 DIMENSIONS

Figure 2-1.

The instrument is supplied in the bench configuration, i.e., in a cabinet with resilient feet for placement on a table. The overall dimensions are given in the figure.

2.3 POWER-LINE CONNECTION.

The power transformer primary windings can be switched, by means of the line voltage switch on the rear panel, to accommodate line voltages in either of 2 ranges, as labeled, at a frequency of 48 to 62 Hz, ac. Using a small screwdriver, set this switch to match the measured voltage of your power line.

Connect the 3-wire power cable (P/N 4200-9625) to the line and to the power connector on the rear panel (Figure 1-2).

The instrument is fitted with a power connector that is in conformance with the International Electrotechnical Commission publication 320. The 3 flat contacts are surrounded by a cylindrical plastic shroud that eliminates the possibility of electrical shock whenever the power cord is being unplugged from the instrument. In addition, the center ground pin is longer, which means that it mates first and disconnects last, ensuring user protection. This panel connector is a standard 3-pin grounding-type receptacle, the design of which has been accepted world wide for electronic instrumentation, and is rated for 250 V at 6 A. It also meets requirements of Underwriter's Laboratories in the U.S. and the Canadian Standards Association. The receptacle accepts power cords fitted with the Belden type SPH-386 connector.

The associated power cord for use with that receptacle is GR part no. 4200-9625. It is a 210-cm (7-ft.), 3-wire, 18-gauge cable with connector bodies molded integrally with the jacket. The connector at the power-line end is a stackable hammerhead design that conforms to the "Standard for Grounding Type Attachment Plug Caps and Receptacles," ANSI C73.11-1966.

If the fuse must be replaced, be sure to use a "slow blow" fuse of the current rating shown on the rear panel, regardless of the line voltage.

2.4 LINE-VOLTAGE REGULATION.

The accuracy of measurements accomplished with precision electronic test equipment operated from ac line sources can often be seriously degraded by fluctuations in primary input power. Line-voltage variations of ±15% are commonly encountered, even in laboratory environments. Although most modern electronic instruments incorporate some degree of regulation, possible power-source problems should be considered for every instrumentation setup. The use of line-voltage regulators between power lines and the test equipment is recommended as the only sure way to rule out the effects on measurement data of variations in line voltage.

The GR 1591 Variac® Automatic Voltage Regulator is a compact and inexpensive equipment capable of holding ac line voltage within 0.2% accuracy for input ranges of ±13%. It will assure, for example, that an instrument rated for 100-125 (or 200-250) V can be operated reliably in spite of varying input voltages in the range 85-135 (or 170-270) V. The 1 kVA capacity of the GR 1591 will handle a rack full of solid-state instrumentation with no distortion of the input waveform. This rugged electromechanical regulator comes in bench or rack-mount versions, each with sockets for standard 2- or 3-wire instrument power cords.

2.5 TEST-FIXTURE CONNECTIONS.

Because an unusually versatile test fixture is provided on the front shelf of the instrument, no test-fixture connection is generally required. Simply plug the device to be measured (DUT) into the test fixture, with or without its adaptors. For details, refer to para 3.2.

The accessory extender cable 1657-9600 is needed to connect to DUT's that are multiterminal, physically large, or otherwise unsuited for the built-in test fixture. (Refer to Table 1-3.) This cable is also needed to connect impedance standards for accuracy checks. Use the following procedure to install the extender cable on the instrument:

a. Remove the adaptors, if present, from the test fixture. See para 3.1.

b. Plug the single-connector end of the extender cable into the test fixture, so that its blades enter both slots, and lock the connector with the 2 captive thumb screws.

c. Notice the color coding of the 5 banana plugs:

I+ = RED P+ = RED/WHITE Guard = BLACK/GREEN
I− = BLACK P− = BLACK/WHITE.

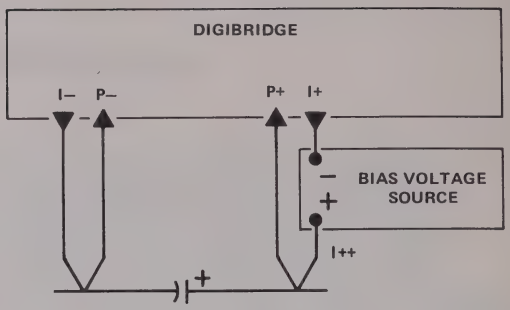

Figure 2-2. Connection of a bias voltage source to enable measurement of capacitors with bias applied. Because the measurement current (up to 30 mA rms) must pass through the bias source, it must be capable of being both source and sink for peaks of about 45 mA. Observe the voltage limits and procedural warnings in the text. Refer to the text also for discharge circuitry.

2.6 EXTERNAL BIAS. Figure 2-2.

WARNING

- **To minimize electrical shock hazard, limit bias to 30 V.**
- **Bias voltage is present at connectors, test fixtures and on capacitors under test.**
- **Capacitors remain charged after measurement.**
- **Do not leave instrument unattended with bias applied.**

For safety of the operator, we recommend that external bias be limited to a maximum of 30 V. If necessary, with suitable precautions, a maximum of 100 V may be used. These precautions must safeguard personnel from dangerous electrical shock. Full bias voltage appears on test leads, bias-voltage-source terminals, and on the leads of the component being measured. Capacitors that have been charged are dangerous until properly discharged; the user must follow safe procedures to assure discharge. For safety, all personnel operating the instrument with bias must be aware of the hazards, follow safe procedures, and never leave the equipment unattended with bias voltage applied.

In order to measure a capacitor with dc bias voltage applied, connect an external voltage source, as follows:

a. Attach the extender cable as described in para 2.5. Observe the color coding explained there.

b. Connect the I+ tip to the negative terminal of a suitable voltage source (see below). Provide a wire from its positive terminal, with a banana plug or alligator clip, which we can designate as the I++ tip.

c. Connect the DUT. If capacitance is large (range 1), make 2 connections to each capacitor terminal (Kelvin connections). That is, I– and P– to capacitor negative terminal; P+ and I++ to capacitor positive terminal.

d. If the capacitance is smaller (range 2 or 3) the banana plugs can be stacked and a single connection made to each capacitor terminal: I–/P– to the negative terminal, P+/I++ to the positive.

e. To make 3-terminal (or 5-terminal) measurements, also connect the G cable tip to the guard terminal, shield, case, or ground of the capacitor, provided that this is insulated from the 2 main terminals of the capacitor. Do not connect G to the case of a capacitor if the case is one of its 2 main terminals.

The bias voltage source must satisfy several criteria:

1. Supply the desired terminal voltage (dc).
2. Serve as source for charging current.
3. Serve as source and sink for the measuring currents (ac), which are 45, 0.45, and .0045 mA, peak, for measurements on ranges 1, 2, and 3, respectively.
4. Present a low, linear terminal impedance ($<< 10\ \Omega$) at measuring frequency.

If the bias voltage source is a regulated power supply with the usual characteristic that it functions properly only as a source, not a sink, then the following test setup is recommended. Connect across the power supply a bleeder resistor that draws dc current at least as great as the peak measuring current (item 3 above). In parallel with the bleeder, connect a 100-μF capacitor. (If the power supply has exceptionally good transient response, the capacitor is not necessary.)

No single bleeder resistor will suffice for all bias conditions, so it may be necessary to switch among several. Each resistance must be small enough to keep the power supply regulator current unidirectional (as mentioned above) for the smallest bias voltage in its range of usefulness. Also the resistance and dissipation capacity must be large enough so that neither the power supply is overloaded nor the resistor itself damaged for the highest bias voltage in its range of application.

NOTE

For convenience, a suitable active current sink can be used in lieu of bleeder resistors.

A discharge circuit is also required. (Do not depend on the above-mentioned bleeder resistor.) A dual discharge circuit is recommended, if more than 30 V is sometimes used. Connect a clip lead with a 10-Ω resistor in series and another plain clip lead to the I–/P– junction. Provide the loose ends of these with insulated alligator clips for use when completing the discharge path across the DUT. For a recommended procedure, refer to para 3.6.

If the measurement program warrants the expense of a test fixture for biased-capacitor measurements, its function should be equivalent to that of the circuit described above. It should be equipped with convenient switching to remove the bias source, discharge through 10 Ω, and finally to short out the capacitor after measurement. For automated test setups, it is also feasible to precharge the capacitors before they are attached to the test fixture and to discharge them after they have been removed.

CAUTION

To avoid damage to the instrument, limit the bias voltage to 30 V, maximum, in any precharging bias supply, used as mentioned above.

2.7 ENVIRONMENT.

The Digibridge can be operated in nearly any environment that is comfortable for the operator. Keep the instrument and all connections to the parts under test away from electromagnetic fields that may interfere with measurements.

Refer to the Specifications at the front of this manual for temperature and humidity tolerances. To safeguard the instrument during storage or shipment, use protective packaging. Refer to Section 5.

Operation – Section 3

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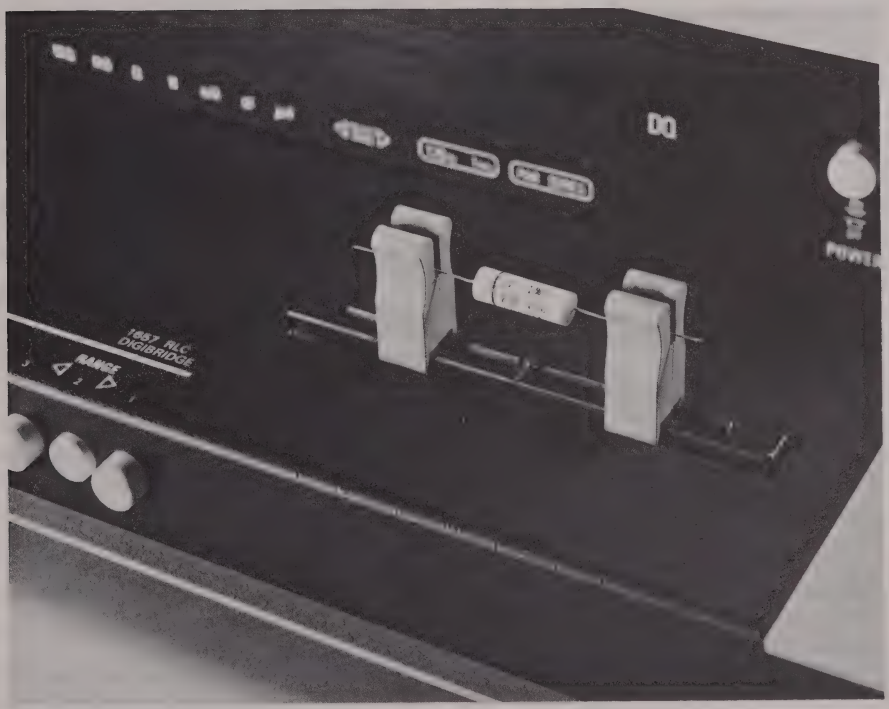

Figure 3-1. Use of the test fixture adaptors.

3.1 BASIC PROCEDURE. Figure 3-1.

For initial familiarization, follow this procedure carefully. After that, use this as a ready reference and refer to later paragraphs in Operation for details.

a. Before connecting the power cord, slide the line-voltage switch (rear panel) to the position that corresponds to your power-line voltage. Power must be 50 to 60-Hz ac in either range: 90 to 127 V or 180 to 254 V. Connect the power cord to the rear-panel connector, from your power line.

b. Connect a typical device, whose impedance is to be measured, as follows. (This device under test is denoted DUT.)

NOTE

Clean the leads of the DUT if they are noticeably dirty, even though the test-fixture contacts will usually bite through a film of wax to provide adequate connections.

Radial-lead DUT. Insert the leads into the test-fixture slots as shown in the photograph, Figure 1-1. For details of wire size and spacing limits, refer to para 3.2.

Axial-lead DUT. Install the test-fixture adaptors, supplied, one in each slot of the test fixture, as shown in the accompanying figure. Slide the adaptors together or apart so the body of the DUT will fit easily between them. Press the DUT down so that the leads enter the slots in the adaptors as far as they go easily. For details of wire size and DUT size limits, refer to para 3.2.

NOTE

To remove each adaptor, lift with a gentle tilt left or right. For a DUT with very short leads it is important to orient each adaptor so its internal contacts (which are off center) are close to the DUT.

Any other DUT or test fixture. Plug the extender cable (see Table 1-3) into the basic test fixture and lock the connector with the 2 captive thumb screws. The branched end of this cable is tipped with 5 stackable banana plugs (adaptable with slip-on alligator clips, supplied), color coded as follows:

Red: I+, current connection to "high" end of DUT.

Red & white: P+, potential connection to same.

Black: I−, current connection to low end of DUT.

Black & white: P−, potential connection to same.

Black & Green: G, guard connection to shield or case (if isolated from the preceding terminals). Do not connect G to the case of a capacitor if the case serves as (or is connected to) one of its 2 main terminals.

Notice that the 2 red tips must connect to the same end of the DUT. The terminals with white bands are potential connections; with no bands, current terminals.

c. Set the pushbuttons according to the desired measurement, as follows:

Power. Depress the POWER button so that it stays in the depressed position. (To turn the instrument off, push and release this button so that it remains in the released position.)

Function. For resistance, depress R. For inductance, depress L/Q. For capacitance, depress C/D. Be sure that one of these buttons is in the depressed position.

Frequency. For measurement at 1 kHz, push and release the FREQUENCY button until the 1-kHz light comes on. For 120 (100) Hz, push the same button so that the 120-Hz (100-Hz) light comes on.

Parallel or Series. For series equivalent circuit, push and release the PARALLEL/SERIES button until the SERIES light comes on. For parallel equivalent circuit, push this button so that the PARALLEL light comes on. (The choice is significant for lossy capacitors or inductors, not for low-loss reactive components or non-reactive resistors.) For further explanation, refer to para 3.5.

Range. Depress the middle (RANGE-2) button first and watch the ADJUST RANGE lights. If the right-pointing arrow is lighted, depress RANGE button at the right. If the left-pointing arrow is lighted, depress RANGE button at the left. When neither arrow is lighted, the range you have selected is correct. (Be sure that one of the RANGE buttons is in the depressed position.) Additional comments on range choices are below.

d. Read the measurement on the main displays. The RLC display is the principal measurement, complete with decimal point and units, which are indicated by the light spot behind MΩ, kΩ, Ω, H, mH, nF, or μF.* The DQ display is D if the C/D FUNCTION button is in, Q if the L/Q button is in.

e. After any change in DUT or measurement conditions, before looking at the displays, notice the ADJUST RANGE lights. Interpret them as follows:

Neither light. Correct range. (There are minor exceptions.)

Left Light. Wrong range; try next RANGE button to left.

Right Light. Wrong range; try next RANGE button to right.

Both Lights. Overrange or invalid display. If FUNCTION is correct and RANGE is highest, the measurement is valid but because of an overrange condition, the basic 0.2% accuracy cannot be guaranteed. (If you switch to RANGE 2, one of the lights will go out.) If both lights are lit on RANGE 2, either the FUNCTION is inappropriate for the DUT or it is not properly connected. For more details, refer to para 3.3.

*If the extender cable is used, it may be necessary to correct for its capacitance.

3.2 CONNECTION OF THE DUT.

3.2.1 The Integral Test Fixture.

The test fixture provided on the front ledge of the Digibridge provides convenient, reliable, guarded 4-terminal connection to any common radial-lead or axial-lead component part.

The slots in the test fixture accommodate wires of any diameter from 0.25 mm (.01 in., AWG 30) to 1 mm (.04 in., AWG 18), spaced from 6 to 98 mm apart (0.23 to 3.9 in.) or equivalent strip conductors. Each "radial" wire must be at least 1 cm long (0.4 in.). The divider between the test slots contains a shield, at guard potential, with its edges exposed. The adaptors accommodate wires of any diameter up to 1.5 mm (.06 in., AWG 15). The body of the DUT that will fit between these adaptors can be 80 mm long and 44 mm diameter (3.1x1.7 in.) maximum. Each "axial" wire must be at least 3 mm long (0.12 in.).

For radial-lead parts, remove each adaptor from the test fixture by a gentle pull upward, made easier by bending the adaptor left or right (never forward or back). For axial-lead parts, insert the adaptors, one in the left slot and the other in the right slot of the test fixture, by pushing vertically downward. They can be slid left and right to match the length of DUT to be measured. Notice that the contacts inside the adaptor are off center; be sure to orient the adaptors so the contacts are close to the body of the DUT, especially if it has short or fragile leads.

Insert the DUT so one lead makes connection on the left side of the test fixture, the other lead on the right side. Insertion and removal are smooth, easy operations and connections are reliable if leads are reasonably clean and straight.

Be sure to remove any obvious dirt from leads before inserting them. The test-fixture contacts will wipe through a film of wax, but will become clogged and ineffectual if you are careless about cleanliness. Be sure the contact pair inside each half of the test fixture is held open by a single item ONLY, whether that is one lead of an axial-lead DUT or one adaptor. (Otherwise you will not obtain true "Kelvin" connections to the DUT.)

3.2.2 The Extender Cable.

The accessory extender cable described in Table 1-3 is needed to connect any DUT that is multiterminal, physically large, or otherwise unsuited for the built-in test fixture. This cable is needed, for example, to connect impedance standards, a remote test fixture, capacitors to be measured with bias, etc. For connection to the instrument, refer to para 2.3. For measurements with bias, refer to para 2.6 and 3.6. The color code for the branched end of the cable is given in para 3.1. To correct for cable capacitance, refer to para 3.7.

3.3 FUNCTION AND RANGE SELECTIONS.

3.3.1 Function Pushbuttons.

The selection of the principal parameter to be measured is almost self-explanatory. Depress the appropriate FUNCTION button: R, L/Q, or C/D to measure resistance, inductance, or capacitance. The instrument will tolerate, to some degree, a poor choice of function, but accuracy is thereby reduced. The readout will indicate a completely wrong choice of function, as explained below. Notice that the appearance of a device can be misleading. (For example, a faulty inductor can be essentially capacitive or resistive; a component part can be mislabeled or unlabeled.)

If both ADJUST RANGE lights are on, the RANGE 2 button is in, the RLC display is blank, and the DUT is properly connected, then the choice of function is probably wrong. Most likely, if the L/Q button is in, the DUT is capacitive; or if the C/D button is in, the DUT is inductive.

Observe the DQ display for an indication of poor choice of function (though tolerable). Large D or small Q may indicate that the "reactor" being measured is practically a resistor at the measuring frequency. If the C/D button is in and the D reading is between 1 and 10 (or blank, as it will be for $D > 10$) it is possible that the DUT is enough like a resistor to be measured best with the R button in. Similarly, if the L/Q button is in and the Q reading is between zero and 1, it is possible that the DUT is enough like a resistor to be measured best with the R button in. Notice that when the R button is in, the DQ display is always blank. On the other hand, any D or Q display is valid, even if the "wrong" function has been selected. (The C or L display can be blank.)

If the R button is in (a resistor is being measured) the easy way to determine whether the DUT is reactive is to try making C/D and L/Q measurements. If you obtain a valid C measurement with $D < 1$, the DUT is capacitive. The smaller this D value, the less accurate the R measurement. Similarly, if you obtain a valid L measurement with $Q > 1$, the DUT is inductive. The larger this Q value the less accurate the R measurement. (See para 3.4.)

3.3.2 Range Pushbuttons.

Range selection is also nearly self-explanatory. Follow the ADJUST RANGE lights. The left light means: "Push the next range button to the left." The right-hand light means: "Push the next range button to the right." Continue until both lights go out. The instrument will usually display a measurement (at reduced accuracy) even though the range is not optimum. The following details about range are best understood with reference to para 3.4 (particularly the RLC basic accuracy graph).

The RANGE buttons are placed in order of decreasing impedance, 3-2-1. The "highest" range is therefore Range 1 for C/D; but it is Range 3 for R and L/Q.

Table 3-1

FULL SCALE READOUTS ON EACH SUBRANGE

Manual range	Automatic subrange	R 1 kHz	R 120 (100) Hz	L 1 kHz	L 120 (100) Hz	C 1 kHz	C 120 (100) Hz
1 (Z_0 = 10 Ω)	1A	19.999 Ω	19.999 Ω	1.9999 mH	19.999 mH	19.999 μF	199.99 μF
	1B*	999.99 Ω	999.99 Ω	99.999 mH	999.99 mH	999.99 μF	9999.9 μF
	1C**	———	———	———	———	———	99999. μF
2 (Z_0 = 1 kΩ)	2A	1.9999 kΩ	1.9999 kΩ	.19999 H	1.9999 H	.19999 μF	1.9999 μF
	2B*	99.999 kΩ	99.999 kΩ	9.9999 H	99.999 H	9.9999 μF	99.999 μF
3 (Z_0 = 100 kΩ)	3A	.19999 MΩ	.19999 MΩ	19.999 H	199.99 H	1.9999 nF	19.999 nF
	3B*	9.9999 MΩ	9.9999 MΩ	999.99 H	9999.9 H	99.999 nF	999.99 nF
	3C**	———	99.999 MΩ	———	———	———	———

*Each "B" subrange covers a full decade (example, 20 to 200 Ω) in the basic range and an upper range extension (example 200 to 999+ Ω), in which accuracy is reduced and the ADJUST RANGE light(s) is on.

**Each "C" subrange is a further extension of the highest range (example, 10 to 99.9+ MΩ).

Each basic range is slightly more than 2 decades wide, from an RLC display of Ø1900, with an automatic decimal-point change between the decades, to 19999. (The symbol Ø represents a blanked zero. Initial zeroes to left of the decimal point are always blanked out of the RLC display.) Each of the 3 ranges goes beyond its basic range, with both upper and lower range extensions (shown by lighter lines in the RLC basic accuracy graph). Several of these extensions are seldom used because they overlap "basic" portions of other ranges and because the operator is alerted to this fact by an ADJUST RANGE light.

Each range includes 2 or 3 subranges, distinguished by the automatic decimal-point shift. The operator does NOT control them. Subranges are detailed in Table 3-1. Notice, for example, if you select RANGE 1, C/D, 1 kHz, then there are 2 subranges: 19-μF and 999-μF. If a series of measurements is made with C increasing slowly above 19 μF, the automatic subrange change takes place at 21. But with C decreasing, the change takes place at 20. This hysteresis eliminates a possible cause of flickering of the display.

The "low" extension of each range goes from Ø1900 down to ØØØ00, without any change in decimal point, but with reduced accuracy. The number of digits in this display is always adequate for the specified accuracy. Any measurement in the low extension of either Range 2 or the highest range causes the appropriate ADJUST RANGE arrow to be lighted. But there is no such light in the low extension of the lowest range (because there is no lower range to select).

The "high" extension of each range is a factor of 5 (with 2 exceptions), going from 19999 up to 99999, and finally to blank, without any change in decimal point, but with reduced accuracy. Any measurement in the high extension of either the lowest range or Range 2 causes the appropriate ADJUST RANGE arrow to be lighted. However in the high extension of the highest range, both ADJUST RANGE arrows are lighted (to indicate a useful "overrange" condition).

The high extension of the top range for R and C only, at 120 Hz (100 Hz) only, is a factor of 50, going from 19999, with an automatic decimal-point change, up to 99999, and finally to blank, with reduced accuracy. (Both ADJUST RANGE arrows are lighted as described above.)

A special case warrants explanation. (This is a minor exception to the basic procedure of para 3.1.) It is possible for both ADJUST RANGE lights to be out and yet the RANGE and FUNCTION buttons to be incorrectly set. This condition results from either faulty connection to the DUT or a numerically small negative L or C measurement. Sometimes a loose or dirty connection to the DUT causes an erratic RLC display. A small negative L or C (wrong function selected) causes a zero display. In either case, check connections at the test fixture and try all 3 FUNCTIONS to see which is appropriate, R, L/Q, or C/D.

3.4 ACCURACY.

3.4.1 Graphs. Figures 3-2, 3-3, and 3-4

The following accuracy graphs supplement the statement of accuracy in the specifications, at the front of this manual.

Figure 3-2 shows that the RLC basic accuracy of 0.2% is realized over 6 decades of impedance if the correct range is selected (as indicated by the ADJUST RANGE lights being out). The reduction of accuracy is shown for all of the "low" and "high" range extensions. This basic RLC accuracy is valid only for "pure" R, L, or C. For the effect

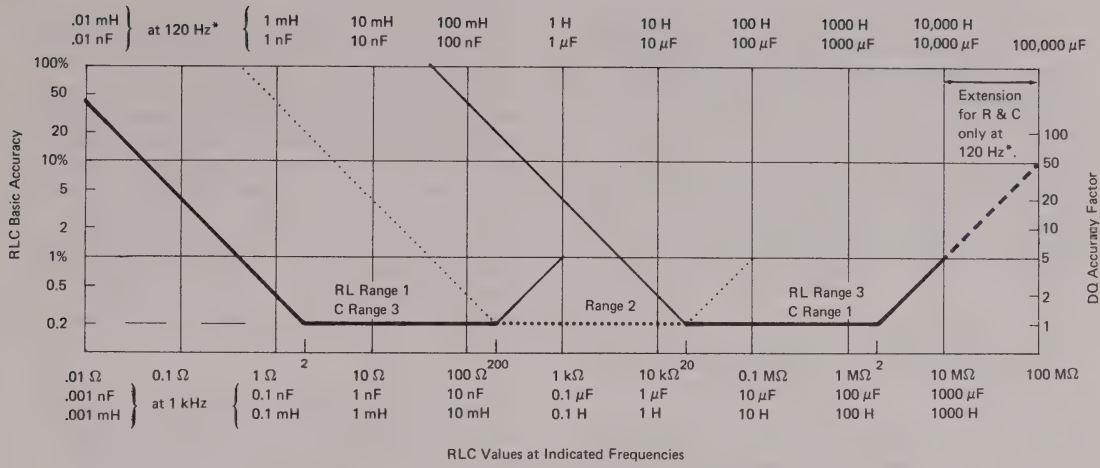

Figure 3-2. R L C basic accuracy as a percent of reading. Heavy lines (solid and dotted) represent best choice of range. Range 2 is dotted. Notice that L and C scales above graph are for 120 Hz (*equally valid for 100 Hz) and the 2 below graph are for 1 kHz. The DQ accuracy factor (right-hand scale) is the multiplier that, applied to the DQ Basic Accuracy, yields complete DQ accuracy, for range extensions as well as the basic ranges (where RLC accuracy is 0.2%).

of quadrature impedance, multiply each basic accuracy value by the RLC accuracy factor; see below.

Figure 3-3 shows the RLC accuracy factor, which depends on D or Q. For example, suppose a capacitor measured at 1 kHz has C = 400 μF and D = 0.5. The RLC basic accuracy is 0.4% and the RLC accuracy factor is 1.5. Therefore, the accuracy of the C measurement is ±0.6%. Notice that the D or Q of a resistor (if significant) can be measured by selecting the C/D or L/Q FUNCTION.

Figure 3-4 shows the basic DQ accuracy, which is simple function of D or Q. For D read the lower scale and lower curve. For Q read the upper scale and upper curve. The basic DQ accuracy is valid only if measurements are made on one of the 3 basic ranges (where RLC accuracy is best). Otherwise, multiply basic DQ accuracy by the DQ accuracy factor, shown on the right of the "RLC basic accuracy" graph. In the example of C = 400 μF, D = 0.5, the basic D accuracy is 0.5% and the D accuracy factor is 2. Therefore, the accuracy of the D measurement is ±1%.

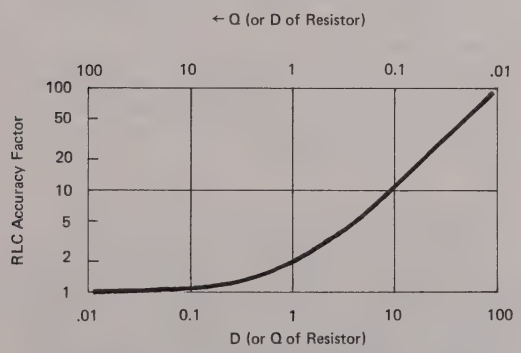

Figure 3-3. R L C accuracy factor as a function of D and Q. Multiply the RLC Basic Accuracy by this factor to obtain complete RLC accuracy for impedances that are not "pure" resistance or reactance. For capacitors and inductors, use the D and Q scales, respectively. For resistors, use the "D of Resistor" scale if capacitive, the "Q of Resistor" scale if inductive.

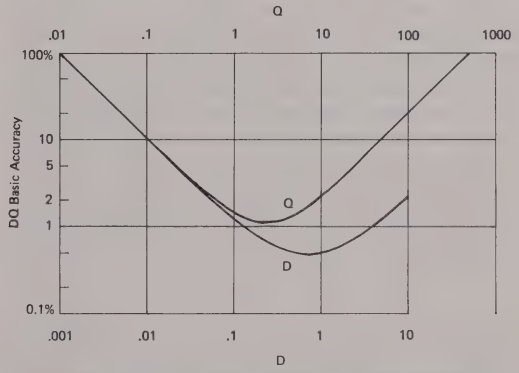

Figure 3-4. DQ basic accuracy as a percent of reading. These curves are directly applicable for measurements in the basic ranges. For measurements on any of the range extensions, refer also to Figure 3-2 for the DQ accuracy factor.

The logarithmic scales on these figures make it very easy to apply the accuracy factors *visually.* For example, suppose a capacitor is being measured on range 2, both ADJUST RANGE lights are out, and the D display is about 1. Figure 3-3 shows that the C accuracy factor is about 1/3 of a decade on the logarithmic scale. On Figure 3-2, find the heavy dotted line (the basic portion of range 2) and point to the basic C accuracy (0.2%) at the left. Now apply the C accuracy factor by moving the pointer up about 1/3 of a decade. The pointer now shows the corrected C accuracy, 0.4%.

3.4.2 Insignificant Digits.

One or more of the digits at the right end of the RLC and/or DQ displays may be insignificant. This is particularly true at the upper extension of a range. If there are more than one insignificant digits in a display, the least significant is typically noisy. That is, it will appear to flicker at random over a range of values and should be ignored.

For example, if you measure a 4-MΩ resistor, the display might ideally be 4.1234 MΩ; but the one or two final digits might be changing at random. This flickering is entirely normal. The specified accuracy (±0.4%) is the key to expected performance; in this example, the last 2 digits are insignificant and the last digit is quite unnecessary. Typically, one would record this measurement as 4.12 ± .02 MΩ.

3.5 PARALLEL/SERIES AND FREQUENCY SELECTIONS.

3.5.1 General.

The value of the principal measurement (R, L, or C) of a certain DUT depends on which of 2 equivalent circuits is chosen to represent it. (Many impedance measuring instruments provide no choice in the matter, but this one allows selection.) The more nearly "pure" the resistance or reactance, the more nearly identical are the "series" and "parallel" values. However, for D or Q near unity, the difference is substantial. Also, the principal measurement often depends on measurement frequency. The more nearly "pure" the resistance or reactance, the less is this dependence. However, for D or Q near unity and/or for measuring frequency near the self-resonant frequency of the DUT, this dependence is quite substantial. We first give general rules for selection of measurement parameters, then some of the theory.

3.5.2 Rules.

Specifications. The manufacturer or principal user of the DUT probably specifies how to measure it. (Usually "series" is specified for C, L, and low values of R.) Select "parallel" or "series" and 1 kHz or 120 Hz (100 Hz) according to the applicable specifications. If there are none known, be sure to specify with your results whether they are "parallel" or "series" and what the measurement frequency was.

Resistors, below about 1 kΩ: Series, 120 Hz (100 Hz). Usually the specifications call for dc resistance, so select a low test frequency to minimize ac losses. Select "series" because the reactive component most likely to be present in a low-resistance resistor is series inductance, which has no effect on the measurement of series R. As a quick check on whether the DUT is nearly pure resistance, make a separate "parallel" measurement. R_p will be larger then R_s. If the difference is less then 1%, then Q is less than 0.1, and the measured R_s is probably very close to the dc resistance.

Resistors, above about 1 kΩ: Parallel, 120 Hz (100 Hz). As explained above, select a low test frequency. Select "parallel" because the reactive component most likely to be present in a high-resistance resistor is shunt capacitance, which has no effect on the measurement of parallel R. As a quick check on whether the DUT is nearly pure resistance, make a separate "series" measurement. If the difference between R_p and R_s is less than 1%, then D is greater than 10, and the measured R_p is probably very close to the dc resistance.

Capacitors below 2 nF: Series, 1 kHz. Unless otherwise specified or for special reasons, always select "series" for capacitors and inductors. This has traditionally been standard practice. Select a high measurement frequency for best accuracy.

Capacitors above 200 μF: Series, 120 Hz (100 Hz). Select "series" for the reasons given above. Select a low measurement frequency for best accuracy and to enable measurement of capacitors larger than 1000 μF.

Inductors below 2 mH: Series, 1 kHz. Select "series" as explained above. Select a high measurement frequency for best accuracy.

Inductors above 200 H: Series, 120 Hz (100 Hz). Select "series" as explained before. Select a low measurement frequency for best accuracy and to enable measurement of inductors larger than 1000 H.

3.5.3 Series and Parallel Parameters. Figure 3-5.

An impedance that is neither a pure reactance nor a pure resistance can be represented at any specific frequency by either a series or a parallel combination of resistance and reactance. Keeping this concept in mind will be valuable in operation of the instrument and interpreting its measurements. The values of resistance and reactance used in the equivalent circuit depend on whether a series or parallel combination is used. The equivalent circuits are shown in Figure 3-5. The relationships between the various circuit elements are as follows.

Resistance and Inductance

$$Z = R_s + j\omega L_s \qquad Z = \frac{j\omega L_p R_p}{R_p + j\omega L_p} \qquad Z = \frac{R_p + jQ^2\omega L_p}{1 + Q^2}$$

$$Q = \frac{1}{D} \qquad Q = \frac{\omega L_s}{R_s} \qquad Q = \frac{R_p}{\omega L_p}$$

$$L_s = \frac{Q^2}{1 + Q^2} L_p \qquad L_s = \frac{1}{1 + D^2} L_p$$

$$L_p = \frac{1 + Q^2}{Q^2} L_s \qquad L_p = (1 + D^2)\, L_s$$

$$R_s = \frac{1}{1 + Q^2} R_p \qquad R_p = (1 + Q^2)\, R_s$$

$$R_s = \frac{\omega L_s}{Q} \qquad R_p = Q\omega L_p \qquad R_p = \frac{1}{G_p}$$

Resistance and Capacitance

$$Z = R_s + \frac{1}{j\omega C_s} \qquad Z = \frac{R_p}{1 + j\omega R_p C_p} \qquad Z = \frac{D^2 R_p + 1/(j\omega C_p)}{1 + D^2}$$

$$D = \frac{1}{Q} \qquad D = \omega R_s C_s \qquad D = \frac{1}{\omega R_p C_p}$$

$$C_s = (1 + D^2)\, C_p \qquad C_p = \frac{1}{1 + D^2} C_s$$

$$R_s = \frac{D^2}{1 + D^2} R_p \qquad R_p = \frac{1 + D^2}{D^2} R_s$$

$$R_s = \frac{D}{\omega C_s} \qquad R_p = \frac{1}{\omega C_p D} \qquad R_p = \frac{1}{G_p}$$

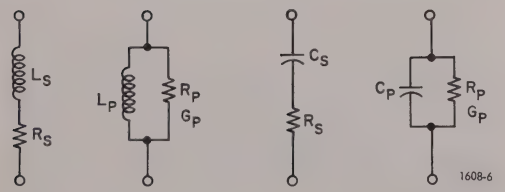

Figure 3-5. Equivalent circuits for a lossy inductor and a lossy capacitor.

3.5.4 Equivalent Series R for Capacitors.

The total loss of a capacitor can be expressed in several ways, including D and "ESR." To obtain equivalent series resistance, one can measure directly (if D is high enough to permit the desired accuracy) or calculate.

Direct Measurement. If, while measuring C, you observe that D is above 0.1 (or some other limit of your choice, see Figure 3-3), push FUNCTION button R and select SERIES.

Both C and ESR should be measured on the same range. If D is below 1, the range should be correct for C, even though the ADJUST RANGE light comes on while you measure ESR. However, if D is above 1, choose the correct "R" range to obtain ESR; and then remeasure C on this range.

Calculation. If D is small, it is better to calculate "ESR" as follows: $R_s = D/2\pi f C_s$, where $\pi = 3.1416$. D and C_s are displayed on the front panel. Frequency f depends on the model of the instrument and the selected frequency as follows (± .01%):
1657-9700: "1 kHz" is 1020.0 Hz; "120 Hz" is 120.0 Hz.
1657-9800: "1 kHz" is 1000.0 Hz; "100 Hz" is 100.0 Hz.

"Equivalent series resistance" is typically much larger than the "ohmic" resistance of the wire leads and foils that are physically in series with the heart of a capacitor. ESR includes also the effect of dielectric loss and is therefore dependent on frequency.

3.5.5 Parallel Equivalent Circuits for Inductors.

Even though it is customary to measure series inductance of inductors, there are situations in which the parallel equivalent circuit better represents the physical device. At low frequencies, the significant loss mechanism is usually "ohmic" or "copper loss" in the wire and the series circuit is appropriate. If there is an iron core, at higher frequencies the significant loss mechanism may be "core loss" (related to eddy currents and hysteresis) and the parallel equivalent circuit is appropriate. Whether this is true at 1 kHz should be determined by an understanding of the DUT, but probably it is so if the following is true: that measurements of L_p at 1 kHz and at 120 Hz (100 Hz) are more nearly in agreement than measurements of L_s at the same 2 frequencies.

3.6 BIAS.

To measure a capacitor with bias applied, it is necessary to insert a bias voltage source in series with the I+ lead to the DUT and to provide a means of discharging it. Refer to para 2.6 for installation of the recommended circuit.

Up to 30 V. No special precautions are required.

WARNING

- **To minimize shock hazard, limit bias to 30 V.**
- **Bias voltage is present at connectors, test fixtures and on capacitors under test.**
- **Capacitors remain charged after measurement.**
- **Do not leave instrument unattended with bias applied.**

Above 30 V. To protect the operator and to avoid damaging the instrument, define a safe procedure like the one that follows and use it regularly:

a. Set the bias voltage to zero.
b. Attach the DUT, with correct polarity.
c. Raise the bias voltage to the specified value.
d. Allow a specified charging and soaking time.
e. Observe and record the specified measurements (usually C_s and D).
f. Set the bias voltage source to zero.
g. Connect the 10-Ω discharging circuit.
h. After about 2 s, connect the safety short circuit.
i. Remove the DUT and the discharging circuits.

3.7 CORRECTION FOR CABLE.

The extender cable adds capacitance in parallel with the DUT (because shielding of the tips is imperfect). The 1657-9600 cable adds about 0.5 pF. Because the physical arrangement and spacing of the cable branches and connectors is significant, a correction should be determined for each measurement setup. The following procedure applies to connection with a precision 3-terminal capacitor, GR 1404 or 1413, for example:

a. Install an adaptor, GR 874-Q2, on each of the two coaxial connectors, L and H, of the capacitor.

b. Connect cable branch G to the ground post of the "low" terminal adaptor. With a clip lead or plain wire, connect this point to the ground post of the "high" adaptor.

c. Connect cable branch P– to the main post of the "low" adaptor and stack I– on top of P–.

d. Similarly, connect P+, with I+ stacked on top of it, to the main post of the "high" adaptor.

e. Measure this total capacitance, the sum of the desired measurement and the cable capacitance, $C_x + C_c$.

f. Carefully lift the stacked pair of cable tips, I+/P+, from the "high" adaptor and hold them about 0.5 cm (1/4 in.) above the binding post where they were connected. Do NOT rearrange the cable branches or change their spacing more than is absolutely necessary to follow these directions. Hold the plastic tips (not the wires) and touch the guard (G) circuit firmly with a couple of fingers, to minimize the effect of capacitance in your body.

g. Measure the cable capacitance, C_c.

h. Subtract the result of step g from that of step e, to obtain the desired measurement, C_x.

Theory—Section 4

4.1 INTRODUCTION 4-1
4.2 PRINCIPAL FUNCTIONS 4-2

4.1 INTRODUCTION.

4.1.1 General.

This instrument uses an unusual method of measurement, which is quite different from those used in previous impedance meters or bridges. A thorough understanding of this method will be helpful in unusual applications of the instrument and be useful in trouble analysis, should malfunction occur. The following paragraph gives a brief overall description outlining the measurement technique to one familiar with impedance measurement methods. A more detailed description of operation, specific circuitry, and control signals is given later.

4.1.2 Brief Description of the 1657 Digibridge.

This Digibridge™ uses a new measurement technique, in which a microprocessor calculates the desired impedance parameters from a series of 8 voltage measurements.* These measurements include quadrature (90°) and inverse (180°) vector components of the voltage across the "unknown" impedance Z_x and the voltage across a standard resistor R_s carrying the same current as Z_x. Each of these measurements is meaningless by itself, because the current through Z_x is not controlled. But the 8 measurements are all made in rapid sequence with the same phase-sensitive detector and analog-to-digital converter. Therefore properly chosen differences between these measurements subtract out fixed offset errors, and ratios between the differences cancel out the value of the common current and the scale factor of the detector-converter.

The phase-sensitive detector uses 4 reference signals, precisely 90° apart, that have exactly the same frequency as the test signal, but whose phase relationship to any of the analog voltages (such as the 8 mentioned above) or currents (such as the current through Z_x and R_s) is incidental. Therefore, no precise analog phase shifter or waveform squaring circuit is required. Correct phase relationships are maintained by generating test signal and reference signals from the same high-frequency source.

There are no calibration adjustments in the Digibridge, thanks to the measurement technique. The only precision components in this instrument are three standard resistors and a quartz-crystal stabilized oscillator. There is no reactance standard. For example, C and D are calculated by the microprocessor from the set of 8 voltage measurements and predetermined values of frequency and the applicable standard resistance.

The microprocessor also controls the measurement sequence, using programs in the ROM memory and a few manual selections. The desired parameters, C and D, L and Q, or R; equivalent circuit, series or parallel; and frequency, either 120 Hz (100 Hz) or 1 kHz, are selected by front panel controls. There are also three manually selected ranges, which have wide overlap. The optimum range for any measurement is indicated by panel lights.

Each range is 2 decades wide, with reduced-accuracy extensions both above and below. For example, consider resistance measurement on Range 1 (Figure 3-2). The 2 decades extend from Ø2.000 Ω, with an automatic decimal-point shift at Ø2.100 going up (at Ø20.00, going down) to 200.00 Ω. The range extensions go as far as can be displayed without further decimal-point shifting: upwards to 999.99 Ω, downwards to ØØ.001 Ω. Leading zeroes before the decimal-point (Ø) are blanked out.

Test frequencies are within 2% of the front-panel indication. However, for reasons related to rejection of power-line-frequency stray signals that could be picked up by the DUT, thereby causing measurement errors, the actual frequencies are as follows —— accurate to ±0.01% ——

catalog number 1657—9700: 1020.0 Hz, 120.00 Hz
catalog number 1657—9800: 1000.0 Hz, 100.00 Hz.

4.1.3 Block Diagram. Figure 4-1.

The block diagram shows the microprocessor (μP) in the upper right corner connected by data and address buses to digital circuitry including RAM and ROM memories, status and control latches, and the front-panel display. Analog circuitry is shown in the lower part of the diagram, where Z_x is supplied with a test signal at frequency f from a sinewave generator, driven by a crystal-controlled digital frequency divider circuit. The front-end amplifier circuit supplies an analog signal that represents 2 impedances alternately: the internal standard, R_s, and the DUT, Z_x.

*Patent applied for.

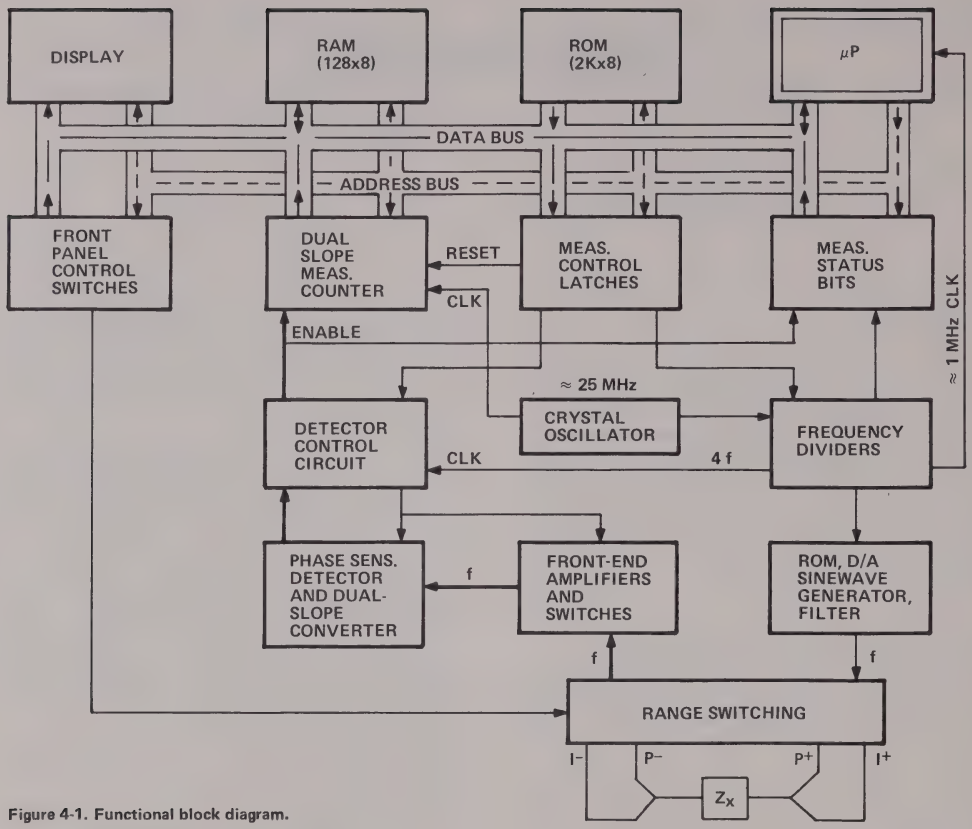

Figure 4-1. Functional block diagram.

The detector control block provides sampling commands (in 4 phases). The detector is a dual-slope converter, including an integrator and comparator, which converts each phase component of the analog signal proportionally into a period of time. The dual-slope measurement is converted into a digital number by a counter that is gated by this period. From this information and manually selected criteria, the microprocessor calculates the RLC and DQ values subsequently displayed.

4.2 PRINCIPAL FUNCTIONS.

4.2.1 Elementary Measurement Circuit. Figure 4-2.

The measurement technique is shown diagrammatically. A sine-wave generator drives current I_x through the DUT Z_x and standard resistor R_s in series. Two differential amplifiers with the same gain K produce voltages e_1 and e_2. Simple algebra, some of which is shown in the figure, leads to the expression for the "unknown" impedance:

$$Z_x = R_s \frac{e_1}{e_2}$$

Notice that this ratio is complex and that (unless you are measuring resistance) both a magnitude and a loss value are automatically calculated from Z_x and frequency.

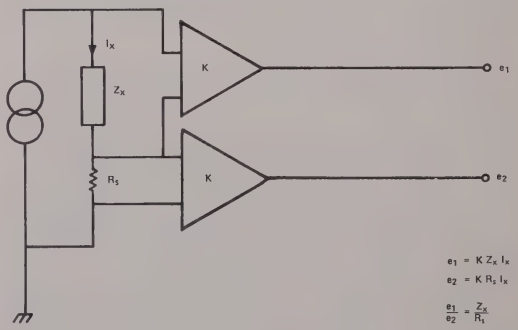

Figure 4-2. Elementary measurement circuit.

4.2.2 Frequency and Time Source. Figure 4-3.

A necessary standard for accuracy is the frequency of the test signal; and equally important are the generation of 4-phase references for detection and clocks for the microprocessor. Frequency and timing requirements are implemented by derivation from a single very accurate oscillator, operating near 25 MHz. Digital dividers and logic circuitry provide the many clocks and triggers, as well as driving the sine-wave generator described below.

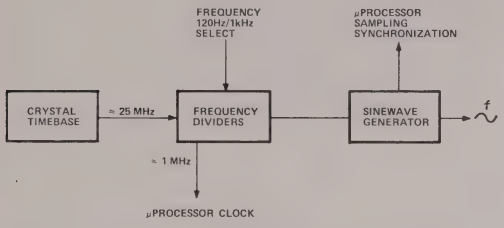

Figure 4-3. Frequency and timing source. A pushbutton determines the frequency select function. Several clocks and synchronizing pulses as well as the measurement signal f are derived from the accurate time-base signal.

4.2.3 Sine-Wave Generation. Figure 4-4.

Starting with a digital signal at 256 times the selected test frequency, the sinewave generator provides the test signal that drives a small but essential current through the DUT.

Binary dividers count down from 256 F, providing 128 F, 64 F, 32 F, . . . 2F, F. This set of signals is used to address a read-only memory which contains a 256-step approximation to a sine function. The ROM output (as an 8-bit binary number) is converted by a D/A converter to a somewhat "noisy" sine-wave, which is then smoothed by filtering before its use in the measurement of a DUT.

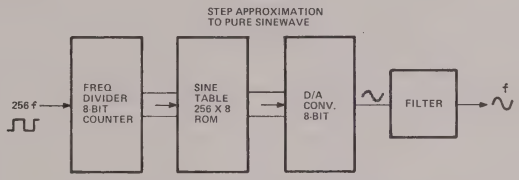

Figure 4-4. Sinewave generator. Given a square wave at 256 f, from preceding dividers, this generator uses a ROM containing the mathematical sine function to form a finely stepped approximation to a sine wave at frequency f. A filter provides smoothing.

Service and Maintenance—Section 5

5.1 CUSTOMER SERVICE 5-1
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WARNING

For continued protection against fire hazard, replace fuse only with same type and rating as shown on rear panel and in parts list.

5.1 CUSTOMER SERVICE.

Our warranty (at the front of this manual) attests the quality of materials and workmanship in our products. If malfunction does occur, our service engineers will assist in any way possible. If the difficulty cannot be eliminated by use of the following service instructions, please write or phone the nearest GenRad service facility (see back page), giving full information of the trouble and of steps taken to remedy it. Describe the instrument by name, catalog number, serial number, and ID (lot) number if any. (Refer to front and rear panels.)

5.2 INSTRUMENT RETURN.

5.2.1 Returned Material Number.

Before returning an instrument to GenRad for service, please ask our nearest office for a "Returned Material" number. Use of this number in correspondence and on a tag tied to the instrument will ensure proper handling and identification. After the initial warranty period, please avoid unnecessary delay by indicating how payment will be made, i.e., send a purchase-order number.

5.2.2 Packaging.

To safeguard your instrument during storage and shipment, please use packaging that is adequate to protect it from damage, i.e., equivalent to the original packaging. Any GenRad field office can advise or provide packing material for this purpose. Contract packaging companies in many cities can provide dependable custom packaging on short notice. Here are two recommended packaging methods.

Rubberized Hair. Cover painted surfaces of instrument with protective wrapping paper. Pack instrument securely in strong corrugated container (350 lb/sq in. bursting test), with 2-in. rubberized hair pads placed along all surfaces of the instrument. Insert fillers between pads and container to ensure a snug fit. Mark the box "Delicate Instrument" and seal with strong tape or metal bands.

Excelsior. Cover painted surfaces of instrument with protective wrapping paper. Pack instrument in strong corrugated container (350 lb/sq in. bursting test), with a layer of excelsior about 6 in. thick packed firmly against all surfaces of the instrument. Mark the box "Delicate Instrument" and seal with strong tape or metal bands.

5.3 REPAIR AND REPLACEMENT OF CIRCUIT BOARDS.

This instruction manual contains sufficient information to guide an experienced and skillful electronic technician in fault analysis and the repair of some circuits in this instrument. If a malfunction is localized to one board (or more) that is not readily repairable, it can be returned to GenRad for repair. To save time, we recommend that you obtain a replacement first, as described below, before returning the faulty board.

Exchanges. For economical, prompt replacement of any etched-circuit board, order an exchange board. Its price is considerably less than that of a new one. Place the order through your nearest GenRad repair facility. (Refer to the last page of this manual.) Be sure to request an exchange board and supply the following information:

1. Instrument description: name and catalog and serial numbers. Refer to front and rear panels.

2. Part number of board. Refer to the parts lists in this manual. (The number etched in the foil is generally NOT the part number.)

3. Your purchase order number. This number facilitates billing if the unit is out of warranty and serves to identify the shipment. The repair facility will arrange for the prompt delivery of a replacement.

To prevent damage to the board, return the defective board in the packing supplied with the replacement (or equivalent protection). Please identify the return with the Return Material number on the tag supplied with the replacement and ship to the address indicated on the tag.

New Boards. For equally prompt replacement of any etched-circuit board, and for maximum life expectancy, order a new one. Use the same procedure as described above, but request a new board. Please return the defective one to GenRad.

5.4 PERFORMANCE VERIFICATION.

This procedure is recommended for verification that the instrument is performing normally. *No other check is generally necessary* because this procedure checks operation of nearly all the circuitry. There are no calibrations or adjustments that could require resetting; and the internal standards are very stable. (However, for a rigorous performance and accuracy check, refer to para 5.5.) The necessary resistors, capacitors, and inductors are inexpensive and readily obtained. The most accurate ones available should be used; tolerances listed are the "best" commonly catalogued. Refer to Table 5-1.

CAUTION

Be sure the line voltage switch, rear panel, is correctly set for your power line voltage.

Verify performance as follows:

a. Set the line voltage switch, connect the power cord, and depress the POWER button.

b. Press the PARALLEL/SERIES button, if necessary, so that the SERIES light stays lit.

c. Press FUNCTION button R.

d. Press the FREQUENCY button, if necessary, so that the 120 Hz (100 Hz) light stays lit.

e. Press the RANGE 1 button.

f. Install the test fixture adaptors, as described in para 3.2. Insert the 49.9-Ω resistor as the device to be tested or "unknown" component (DUT).

g. Verify that the displays are within the extremes shown in "check number 1" in Table 5-2, if the resistor value is within the tolerance listed above.

h. Similarly make the other checks indicated in this table. In check number 12, verify that the 5th digit is reasonably stable, as follows. (Notice that the 4th digit is the least significant one in the readout, for 0.2% accuracy.)

i. In check number 12, the flickering of the 5th digit should stay typically within a range of ±3 counts. For example, if the display is 1.101X μF, the "X" might flicker between 2 and 8 (or a smaller range). If, for example, "X" is flickering between 7 and 13, it will of course cause a flickering of the preceding digit (1.1017 to 1.1023). In such a case, the correct readout is the larger 4-digit number (1.102) and the 5th digit is acceptably stable.

Tolerances. Acceptable performance of the instrument is bracketed by the set of display "extremes" in Table 5-2. These are defined as the nominal (ideal) measurements plus-or-minus the sum of the instrument accuracy tolerance and twice the DUT accuracy tolerance. If the accuracy of your DUT is different from the recommendation, revise the acceptable "extremes" accordingly. Notice that this performance verification is NOT intended to prove the accuracy of the instrument.

Table 5-1

RESISTORS, CAPACITORS, AND INDUCTORS

Name	Type*	Nominal Value	Tolerance
Resistors, metal film	MIL-R-10509C (style RN60)	49.9 Ω	0.1%
		499 Ω	0.1%
		4.99 kΩ	0.1%
		49.9 kΩ	0.1%
		499 kΩ	0.1%
Capacitors, polystyrene	Arco: 1PJ-332J	0.0033 μF	0.5%
	1PJ-333J	0.033 μF	0.5%
	1PJ-334J	0.33 μF	0.5%
	1PJ-504J	0.5 μF	0.5%
metalized polyester	GE: BA-14A105C	1.0 μF	5%
	BA-19A106C	10 μF	5%
Inductors, nonferrous	J.W. Miller 9220-28	1000 μH	5%
ferrite core	9250-107	100 mH	10%

*Equivalents may be substituted.

Table 5-2

PERFORMANCE VERIFICATION

Check Number	Function; Frequency	Range	DUT	RLC Display Extremes**	DQ Display Extremes**
1	R; 120 Hz*	1	49.9 Ω	Ø49.70 to Ø50.10 Ω	Blank
2		2	499 Ω	Ø.4970 to Ø.5010 kΩ	
3		2	4.99 kΩ	Ø4.970 to Ø5.010 kΩ	
4		3	49.9 kΩ	.04970 to .05010 MΩ	
5		3	499 kΩ	Ø.4970 to Ø.5010 MΩ	
6	C/D; 1 kHz	3	.0033 μF	Ø3.260 to Ø3.340 nF	(.0000 to .0100)
7	120 Hz*	3	.0033 μF	Ø3.260 to Ø3.340 nF	
8	1 kHz	2	.033 μF	.03260 to .03340 μF	
9	120 Hz*	3	.033 μF	Ø32.60 to Ø33.40 nF	(.0000 to .0100)
10	both freq	2	0.33 μF	Ø.3260 to Ø.3340 μF	
11	both freq	2	0.5 μF	Ø.4940 to Ø.5060 μF	
12	both freq	2	1.0 μF	Ø.8980 to 1.1020 μF	(.0000 to .0300)
13	1 kHz	1	10 μF	Ø8.980 to 11.020 μF	
14	120 Hz*	2	10 μF	Ø8.980 to 11.020 μF	
15	L/Q; 1 kHz	1	1000 μH	Ø.8980 to 1.1020 mH	(Ø3.00 to 300.0)
16		2	100 mH	.07980 to .12020 H	(Ø3.00 to 300.0)
17	C/D; 1 kHz	2	Series***	.03260 to .03340 μF	.1030 to .1080***
18	1 kHz	2	Series***	.03260 to .03340 μF	.0094 to .0117***

*120 or 100 Hz.

**Refer to paragraphs headed "Tolerances" and "Insignificant figures."

***Refer to paragraph headed "Series DUT." The tabulated D extremes apply to the 1657-9700; for the 1657-9800, in step 17 substitute .1010 to .1059, in step 18 substitute .0092 to .0115.

Insignificant figures. The right-hand digit(s) of the display normally flicker and change if they are not significant for the specified accuracy of the instrument. Refer to para 3.4.

Series DUT. For check number 17 of Table 5-2, the DUT is a series connection of 0.033 μF and 499 Ω; for check 18, 0.033 μF and 49.9 Ω. For these checks, remove the adaptors from the test fixture. Insert the resistor in one side and the capacitor in the other side, both slanted so their upper leads cross each other. Clamp them together with a small alligator clip or paper clip.

5.5 MINIMUM PERFORMANCE STANDARDS.

5.5.1 General.

This procedure is a more rigorous alternative to the performance verification described above. Precision standards of impedance are required for this procedure, which checks the accuracy as well as the overall performance of the instrument. It will be controlled from the front panel, without disassembly. Table 5-3 lists the recommended standards and associated equipment.

Verify that the instrument meets performance specifications as follows. Notice that the specifications in the front of this manual supercede any that are tabulated below.

Calibration of Standard. The acceptable RLC readout (min to max range) may have to be modified if your actual Z_X or Z_X accuracy is different from the value tabulated. For example, if your 1-kΩ standard is actually 1.005 kΩ, known to ±0.1%, then the acceptable readout is 1.005 ±0.3%, i.e., 1.0020 (min) to 1.0080 (max) kΩ. (Refer to check E of Table 5-4.)

Insignificant Digits. The right-hand digit(s) of the display normally may flicker and change if they are not significant for the specified accuracy of the instrument. Refer to para 3.4.

Cable Capacitance. Because the cable adds capacitance in parallel with the DUT, it is sometimes necessary to obtain a "corrected readout" from the numerical display on the instrument. Do this for all checks involving small capacitance (about 1000 pF or less). The equivalent correction for large inductance (above 30 H at 1 kHz or 3000 H at 120 Hz) is not applicable in the recommended inductance check procedure. For capacitance measurement, obtain the corrected readout by subtracting the cable capacitance from the visible readout, as described in para 3.7. Because C is large compared to cable capacitance and D is small, the simple calculation (subtraction) is applicable whether the measurement is "parallel" or "series."

CAUTION

Be sure the line voltage switch, rear panel, is correctly set for your power line voltage.

Table 5-3

EQUIPMENT FOR ACCURACY VERIFICATION AND TROUBLE ANALYSIS

Name	Requirements	Recommended Type*
Extender cable	Adapts test fixture to standards with binding post and banana plugs.	GR 1657-9600
Resistors	Four-terminal, 1 Ω, .02%	GR 1440-9601
	10 Ω, .01%	GR 1440-9611
	Decade, 100 to 11 111 000 Ω, 0.01%	GR 1433-9719 (-Y)
Capacitors	Three-terminal, 100 pF, 0.003%	GR 1404-9702 (-B)
	1000 pF, 0.003%	GR 1404-9701 (-A)
	1 μF, 0.02%	GR 1409-9725 (-Y)
	Decade, 3-T, 1 pF to 1^{+} μF, 0.05% ± 0.05 pF	GR 1413-9700
	Four-terminal, ratio type, 1 μF to 10 mF, 0.25% (ratios, 0.02%)	GR 1417-9700
	Dc Blocking, 500 μF, 10 V	GE 69F2214G2
Inductors	Fixed, 2-terminal, 100 μH, 0.25%	GR 1482-9702 (-B)
	1 mH, 0.1%	GR 1482-9705 (-E)
	10 mH, 0.1%	GR 1482-9708 (-H)
	100 mH, 0.1%	GR 1482-9712 (-L)
	1 H, 0.1%	GR 1482-9716 (-P)
	10 H, 0.1%	GR 1482-9720 (-T)
Adaptors	GR874® (see 1413 capacitor) to banana plugs (2 required)	GR 0874-9870 (-Q2)
Scope**	General purpose, 100 MHz, dual trace	Tektronix 465
Scope probe**	Capacitance < 10 pF, X10	Tektronix P6053B
Voltmeter**	Digital, general purpose	Data Precision 2540, with probe
Counter**	Dc to 35 MHz, 10 mV rms	GR 1191
Pulse generator**	General purpose	GR 1340
Resistor**	200 Ω, 1/4 W	——

*Equivalents may be substituted.
**Required for trouble analysis (paragraph 5.8). Not required for paragraph 5.5.

Table 5-4

RESISTANCE ACCURACY CHECKS

Check Sequence	Frequency; Function; Parallel/Series	Range	R_X (exact value)	R_X Accuracy	Instrument Accuracy	RLC Readout** Min to Max
A	120 Hz*; R; series	1	1 Ω	.02%	0.4%	Ø0.996 to Ø1.004 Ω
B	1 kHz; R; series	1	1 Ω	.02%	0.4%	Ø0.996 to Ø1.004 Ω
C	1 kHz & 120 Hz*	1	10 Ω	.01%	0.2%	Ø9.979 to 10.021 Ω
D	Same (both freq)	1	100 Ω	.01%	0.2%	Ø99.79 to 100.21 Ω
E	Same	2	1 kΩ	.01%	0.2%	Ø.9979 to 1.0021 kΩ
F	Same	2	10 kΩ	.01%	0.2%	Ø9.979 to 10.021 kΩ
G	Same except parallel	3	100 kΩ	.01%	0.2%	.09979 to .10021 MΩ
H	Same (parallel)	3	1 MΩ	.01%	0.2%	Ø.9979 to 1.0021 MΩ
I	120 Hz*; R; parallel	3	11 MΩ	.01%	1.1%	10.878 to 11.122 MΩ

*Either 120 or 100 Hz.
**Tabulated readout is based on tabulated R_X and R_X accuracy. Refer to para 5.1.1.

5.5.2 Resistance Measurement Accuracy.

a. Set the line voltage switch, connect the power cord, and depress the POWER button. Allow 5 minutes for warm-up (during which time steps b through f can be done) before accuracy determination.

b. Press the PARALLEL/SERIES button, if necessary, so that the SERIES light stays lit.

c. Press the FUNCTION button R.

d. Press the FREQUENCY button, if necessary, so that the 120 Hz (100 Hz) light stays lit.

e. Press the RANGE 1 button.

f. Connect the 1-Ω standard resistor to the test fixture, using the extender cable, as described in para 3.1. Connect cable I+ and I– to the posts on the front of the resistor, and P+ and P– to the corresponding plugs on the back. (Leave G of the cable unconnected.)

g. Verify that the RLC readout is between the min and max extremes tabulated for check A in Table 5-4. (Refer to para 5.5.1 for exceptions.)

h. Continue through the checks specified in the table. Connect to the decade resistor (checks D, E, etc.) as follows: stack cable tips I+ on P+ and plug them into resistor terminal H; stack I– on P– and plug them into L; connect G to G.

5.5.3 Capacitance Measurement Accuracy.

Continue as in the resistance accuracy procedure, above, except as follows:

a. Follow Table 5-5 for details of setup and performance.

b. Refer to para 3.7, for details of connection to 3-terminal capacitors with coaxial connectors and for the determination of cable capacitance. The corrected readout of capacitance is the actual display minus the cable capacitance.

CAUTION

Do NOT connect the 1417 capacitor without a dc blocking capacitor in series with the connection between the CURRENT H terminal and the Digibridge (I+ terminal).

c. For C standards greater than 1 μF (checks R, S, T . . .), using the GR 1417 Four-Terminal C Standard, connect a 500-μF dc blocking capacitor between the CURRENT H terminal and the I+ tip of the extender cable from the Digibridge. (Orient the blocking capacitor: + to the cable.)

d. For C standards greater than 1 μF, C_X accuracy better than that indicated in the table can be realized by a calibration of the 1-μF value and proportional correction of the higher values of the GR 1417. Typical accuracy is 0.06% if the GR 1413 is used as the standard. (Refer to the 1417 instruction manual for details.) However, for a C_X accuracy of about 0.25%, no calibration is required.

5.5.4 D Measurement Accuracy.

Continue with the accuracy procedure as follows:

a. For DUT, make a series connection of the R and C decade boxes, by connection from the high (H) terminal of the resistance box to the inner low (L) terminal of the capacitance box. Stack cable tips I+ and P+ and connect these to the inner high (H) terminal of the capacitance box. Similarly stack I– and P– on low (L) of the resistance

Table 5-5

CAPACITANCE ACCURACY CHECKS

Check Sequence	Frequency; Function; Parallel/Series	Range	C_X Actual	Typical C_X Accuracy	Instrument Accuracy	Corrected RLC Readout Min to Max**
J	1 kHz; C/D; series	3	100 pF	.003%	0.4%	Ø.0996 to Ø.1004 nF
K	1 kHz	3	1000 pF	.003%	0.2%	Ø.9977 to 1.0023 nF
L	120 Hz*	3	1000 pF	.003%	0.4%	Ø.9956 to 1.0043 nF
M	1 kHz and 120 Hz*	3	0.01 μF	.05%	0.2%	Ø9.975 to 10.025 nF
N	120 Hz*	3	0.1 μF	.05%	0.2%	Ø99.75 to 100.25 nF
O	1 kHz	2	0.1 μF	.05%	0.2%	.09975 to .10025 μF
P	1 kHz	2	1 μF	0.02%	0.2%	Ø.9978 to 1.0022 μF
Q	120 Hz*	2	1 μF	0.03%	0.2%	Ø.9977 to 1.0023 μF
R	120 Hz*	2	10 μF	0.25%**	0.2%	Ø9.955 to 10.045 μF
S	1 kHz	1	10 μF	0.25%	0.2%	Ø9.955 to 10.045 μF
T	1 kHz	1	100 μF	0.25%	0.2%	Ø99.55 to 100.45 μF
U	120 Hz*	1	100 μF	0.25%	0.2%	Ø99.55 to 100.45 μF
V	120 Hz*	1	1 mF	0.25%	0.2%	Ø995.5 to 1004.5 μF
W	120 Hz*	1	10 mF	0.25%	1%	9875.0 to 10125 μF

*Either 120 or 100 Hz.

**Correct actual display for cable capacitance. Slightly different min and max obtain if C_X and C_X accuracy are different from tabulated values. Refer to para 5.5.1. In particular, steps R . . . W can be made more exacting, with acceptable values of C readout that depend on C_X calibration, as explained in the text.

box. (Be sure this is not strapped to G.) Connect cable tip G to G of the resistance box and to the outer terminals of the capacitance box.

b. Follow the checks in Table 5-6. Notice that the capacitor settings depend on catalog number of the instrument as well as front-panel frequency settings. Refer to the footnotes in the table.

Also notice that the sequence of checks AA . . . AG is made by varying only R_S. The sequence BA . . . BG is not tabulated in detail because it involves exactly the same settings of R_S and corresponding DQ readouts. (The first and last of this sequence are tabulated for illustration.)

5.5.5 Inductance Measurement Accuracy.

Continue as in the resistance and capacitance accuracy procedures except as follows.

a. Follow Table 5-7 for details of setup and performance.

b. For check "CA", the GR 1482-B inductor must be measured twice, i.e., once with a shorting link from center to left "reference" terminals, once with the link from center to right. (Connect the extender cable to the "connection" terminals, NOT the "reference" terminals.) The difference between these 2 measurements is the corrected readout. For each other check, CB, CC, CD . . . , a single measurement is sufficient. Refer to "Method of Measurement" on the calibration certificate of the inductor.

c. Notice that the low-frequency checks are somewhat limited by the low Q's of the standard inductors. A Q of 1 or less causes a factor of 2 or more degradation in the specified accuracy of inductance measurement.

5.6 DISASSEMBLY AND ACCESS.

WARNING

If disassembly or servicing is necessary, it should be performed only by qualified personnel familiar with the electrical shock hazards inherent to the high-voltage circuits inside the cabinet.

CAUTION

Observe the following precautions whenever you handle a circuit board or integrated circuit in this instrument.

MOS HANDLING PRECAUTIONS

- **Place instrument and parts on a grounded, conductive work surface.**
- **Ground yourself (with a strap having about 1 MΩ resistance).**
- **Ground the frame of any test instrument or soldering iron used.**
- **If any circuit boards are to be stored or transported, enclose them in conductive (anti-static) envelopes.**

Table 5-6

DISSIPATION-FACTOR ACCURACY CHECKS

Check Sequence	Frequency; Function; Parallel/series	Range	R_S; C_S	Nominal D	Typical D Accuracy	Instrument Accuracy	DQ Readout Min to Max
Z	1 kHz; C/D; series	2	100 Ω; C_1 *	.0096	.07%	10.6%	.0086 to .0106
AA	Same	2	100 Ω; C_2 *	0.0192	.07%	5.4%	.0182 to .0203
AB	Same	2	300 Ω; C_2	0.0577	.07%	1.95%	.0565 to .0588
AC	Same	2	1 kΩ; C_2	0.1923	.07%	0.76%	.1907 to .1939
AD	Same	2	3 kΩ; C_2	0.5768	.07%	0.49%	.5736 to .5800
AE	Same	2	10 kΩ; C_2	1.923	.07%	0.64%	1.909 to 1.936
AF	Same	2	30 kΩ; C_2	5.768	.07%	1.37%	5.687 to 5.849
AG	Same	2	50 kΩ; C_2	9.613	.07%	2.13%	9.402 to 9.825
BA	120 Hz**; C/D; series	2	100 Ω; C_3 **				.0182 to .0203
. . .	Same	2	. . . . C_3				(See text)
BG	Same	2	50 kΩ; C_3				9.402 to 9.825

*For 1657-9700 (f = 1020 Hz), C_1 = .0150 and C_2 = .0300 μF.
For 1657-9800 (f = 1000 Hz), C_1 = .0153 and C_2 = .0306 μF.
**For 1657-9700 (f = 120 Hz), C_3 = 0.255 μF.
For 1657-9800 (f = 100 Hz), C_3 = 0.306 μF.

Table 5-7

INDUCTANCE ACCURACY CHECKS

Check Sequence	Frequency; Function; Parallel/Series	Range	Effective L_S	Expected Q	Accuracy of L_S; Instrument	RLC Readout* Min to Max
CA	1 kHz; L/Q; series	1	100 μH	7.6	0.12; 0.45%	Ø.0994 to Ø.1006 mH
CB	1 kHz	1	1 mH	7.5	.03; 0.23%	Ø.9974 to 1.0026 mH
CC	120 Hz	1	1 mH	0.90	.03; 0.84%	Ø.9913 to 1.0087 mH
or	100 Hz			0.75	.03; 0.93%	Ø.9904 to 1.0096
CD	120 Hz	1	10 mH	0.92	.02; 0.42%	Ø9.956 to 10.044 mH
or	100 Hz			0.77	.02; 0.46%	Ø9.952 to 10.048
CE	1 kHz	1	10 mH	7.7	.02; 0.23%	Ø9.975 to 10.025 mH
CF	120 Hz	1	100 mH	0.94	.02; 0.41%	Ø99.57 to 100.43 mH
or	100 Hz			0.78	.02; 0.46%	Ø99.52 to 100.48
CG	1 kHz	2	100 mH	7.7	.02; 0.23%	.09975 to .10025 H
CH	1 kHz	2	1 H	10.	.02; 0.22%	Ø.9976 to 1.0024 H
CI	120 Hz	2	1 H	1.2	.02; 0.37%	Ø.9961 to 1.0039 H
or	100 Hz			1.0	.02; 0.40%	Ø.9958 to 1.0042
CJ	120 Hz	2	10 H	1.18	.02; 0.37%	Ø9.961 to 10.039 H
or	100 Hz			0.98	.02; 0.40%	Ø9.958 to 10.042
CK	1 kHz	3	10 H	9.8	.02; 0.22%	Ø9.976 to 10.024 H

*Tabulated readout is based on tabulated L_S and L_S accuracy. Refer to para 5.5.1.

5.6.1 Disassembly. Figures 5-1 through 5-6.

Use the following procedure for access to replaceable parts and contact points used in trouble analysis.

a. Disconnect the power cord.

b. Remove the top-cover screws from the rear panel of the main chassis. See Figure 1-2. Slide the top cover forward about 6 mm, so that its front corners are unhooked. Lift it directly upward (Figure 5-1). Reassembly note: 2 screws, 13 mm long.

The next step, removal of display board, is recommended (though not absolutely necessary) before removal of the main circuit board.

c. Remove the 2 screws, at left and right, that hold the display board to its support brackets. (See illustration in para 5.6.2.) Pull the board directly out of its socket in the main board. Keep the display board in its original (inclined) plane until it is completely free (Figure 5-2).

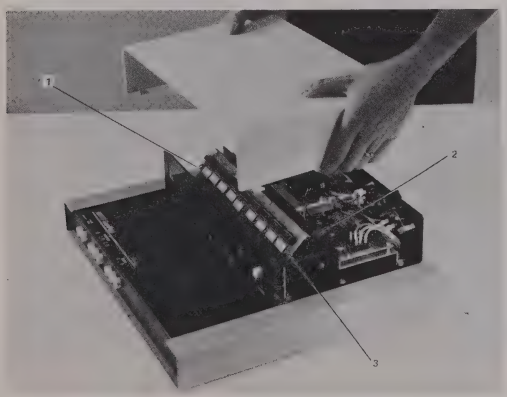

Figure 5-1. Removal of top cover. Items 1 and 3 are screws that hold the display board. Item 2 is ribbon cable 1657-0200 that connects power supply to C board.

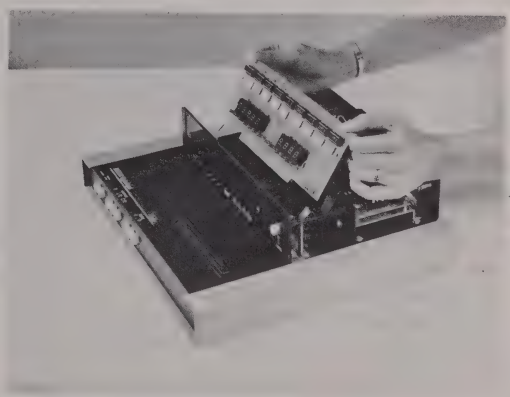

Figure 5-2. Removal of the display board.

d. Remove the ribbon cable (1657-0200) from power supply (at V-J1) and main board (at C-J1). Notice that the connectors are symmetrical and reversible; and the cable is extra long, for convenience in servicing.

The next step, removal of the power supply, is NOT related to the removal of the main board. Either can be left in place while the other is removed.

e. Remove the 4 screws that pass vertically through the corners of the power supply into the main chassis. Lift the power supply slightly and move it back carefully while disengaging the POWER pushbutton extension from its hole in the front panel (Figure 5-3). Reassembly note: 4 screws, 8 mm long.

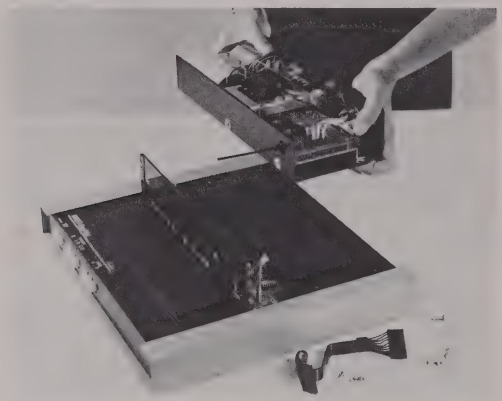

Figure 5-3. Removal of the power supply. The ribbon cable must be disconnected first. The display board can be left in place, but has been removed in this picture.

f. After disconnecting the ribbon cable, provide a convenient "upsidedown" support by reinstalling the top cover, temporarily. Turn the instrument, bottom up.

g. Remove 4 screws from the bottom shell, one near each rubber foot. Slide the bottom shell back (or forward), free of the main chassis (Figure 5-4). Reassembly notes: Be sure to enfold the pliable dirt seals at left and right sides of main chassis as you start to slide bottom shell onto main chassis; use 4 screws, 8 mm long.

h. Remove 8 screws shown in Figure 5-5 as ABCGHI (7 mm) and EJ (8 mm). Lift the rear edge of the main board as shown in Figure 5-6 and slide it back until clear of the main chassis.

i. For access to the test-fixture contacts, which are on the main board, remove screws KL and drop the test-fixture guide block off of the test fixture contacts. Refer to bottom interior view, Figure 5-5.

Notice that it is possible to remove the main board with the display board mounted on it, by this procedure: release all 8 front pushbuttons; remove screws ABCEGHIJ; lift rear edge of main board 25 mm and slide it forward 16 mm; lift rear edge to 75 mm (so display board clears cutout in main chassis) and slide the assembly back until display board reaches spacer; lift rear edge another 15 mm and slide it back until pushbuttons are free; lift assembly out.

Reassembly note: install screw "I," loosely. Position test fixture as desired (preferably symmetrical in its opening), before installing screws A, E, etc.

Figure 5-4. Removal of the bottom shell. The top cover has been temporarily installed as a support.

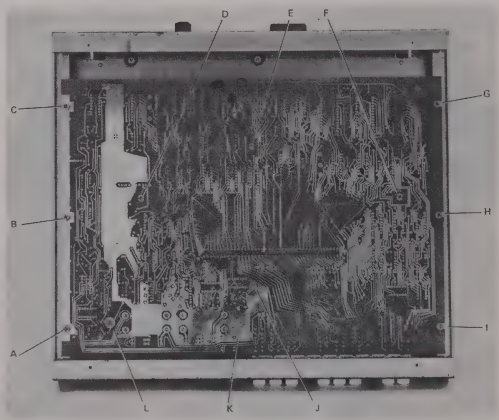

Figure 5-5. Bottom interior view. Screws ABCEGHIJ hold the C board to the chassis. Screws DF hold display-board brackets. Screws KL hold the test-fixture guide block.

Figure 5-6. Removal of the C board. The ribbon cable must be disconnected first. Prior removal of the display board also is highly recommended.

5.6.2 Access. Figures 5-7 and 5-8.

Locations of principal interior parts and points of interest for trouble analysis are shown in these 2 pictures. Notice the keys to orientation of IC and other component parts (Pin 1 is generally connected to a square pad, if the part is board-mounted.) On the main board, the crystal and 2 jumpers are identified that have to be changed to convert a 1657-9700 functionally to a 1657-9800, and vice versa. (Thus, with a spare crystal, one can obtain 3 test frequencies, 100, 120, and 1000 Hz.)

Also on the main board, notice that the front right-hand area, approximately designated by 2 arrows with letters "A", contains the analog "front end" circuitry. The rest of the board contains digital circuitry.

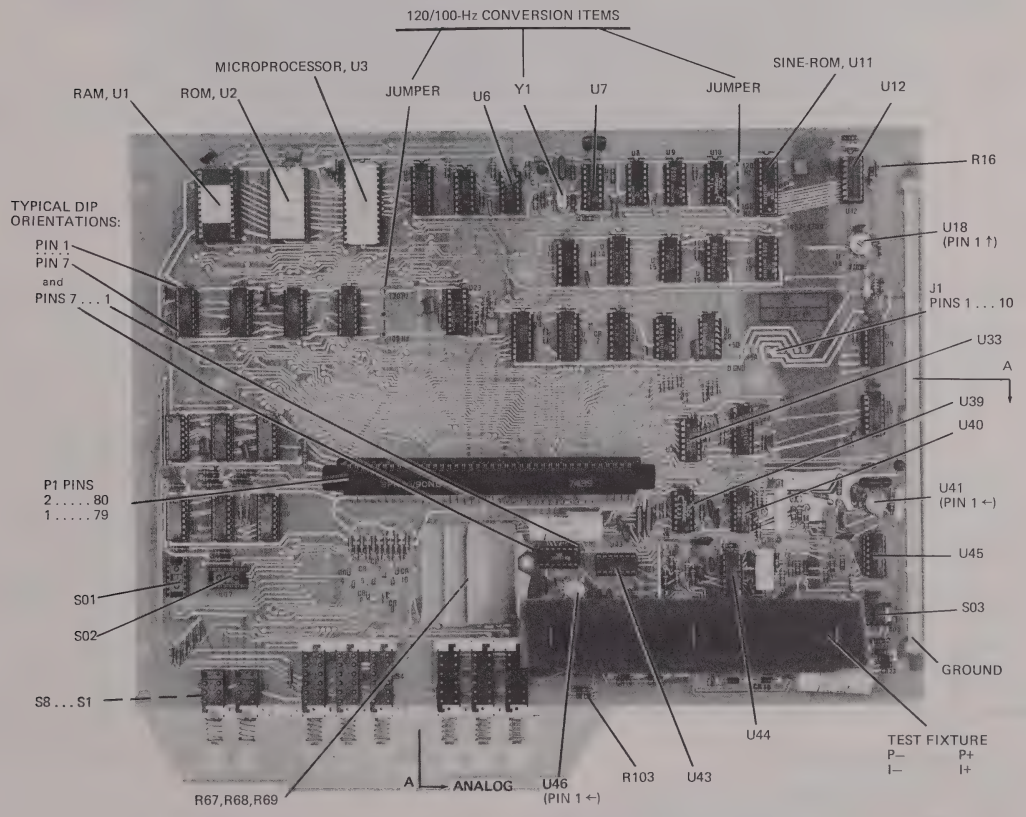

Figure 5-7. Main or C board, top view. Functional conversion between 1657-9700 and 1657-9800 involves replacement of precision oscillator (or crystal Y1, if separate) and relocation of 2 jumpers; locations indicated. Notice that DIP sockets are oriented consistently, for convenience in circuit probing. Arrows A———A indicate approximately the area of analog circuitry.

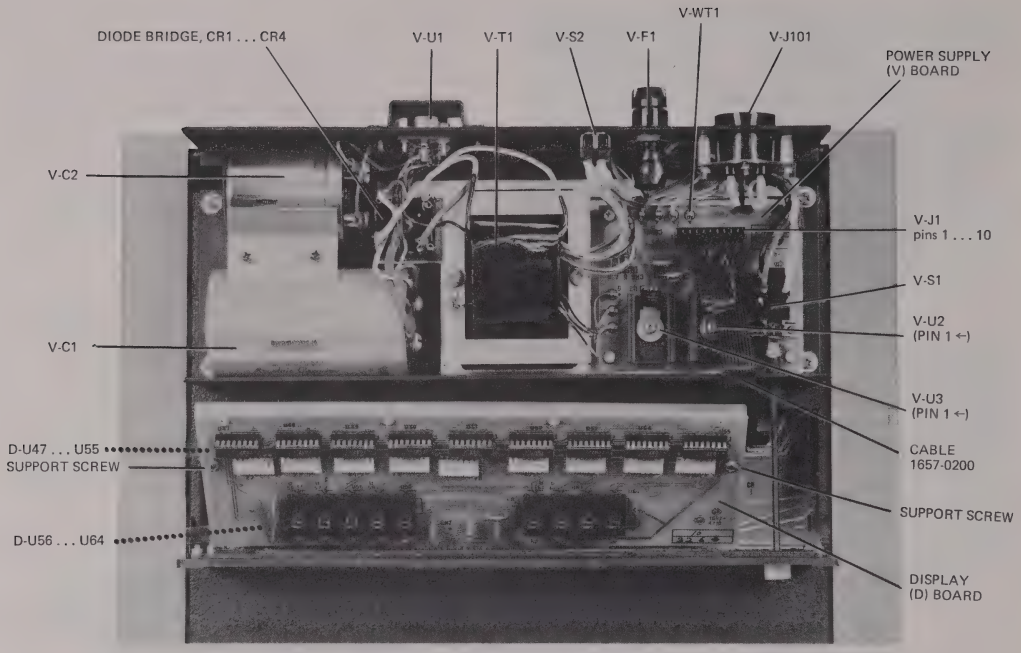

Figure 5-8. Power supply (V assembly) and display or D board, shown in the instrument, with top cover off.

5.6.3 Reference Designations.

Refer to Section 6 for an explanation of these designations. For example, V-T1 designates transformer number one in the power supply (V) assembly. C-U3 is integrated circuit number 3 on the C board, which is the analog and control board or the main board.

5.6.4 Removal of Multiple-Pin Packages.

Use caution when removing a plug-in integrated-circuit or other multiple-pin part, not to bend pins nor stress the circuit board. Withdraw the part straight away from the board. Unless an IC is known NOT to be a MOS type, place it immediately on a conductive pad (pins in the pad) or into a conductive envelope.

Do NOT attempt to remove a soldered-in IC package without the proper equipment and skills to do so without damage. If in doubt, return the board to GenRad.

5.7 PERIODIC MAINTENANCE.

5.7.1 Care of the Test Fixture.

About once a year (more or less depending on usage) the test fixture should be inspected and cleaned as follows:

a. Remove the C board and expose the text-fixture contacts by removing its guide block (part number 1657-2200), as described above. See Figure 5-5, screws KL.

b. Clean and check the 4 contact strips. Use a card wet with isopropyl alcohol for cleaning. Hold the board at an angle so that any drip falls away from the circuits.

c. If necessary, the contact strips (part number 1686-1940) can be removed (2 screws apiece). They are supposed to press against each other, with tiny dielectric spacers preventing contact. Except at the ends of the gap (where the spacers are) the gap should be .05 to 0.2 mm (.002 to .008 in.) all along the gap. If accurate feeler gages are not available, the following criterion can be used: the gap should be large enough to pass a strip of ordinary typing paper without dragging, but narrow enough everywhere (at center and near each end) to cause some drag as a stack of 3 strips of paper is passed through.

For best results and minimum maintenance effort, the operator must remove any obvious dirt from leads of DUT's before inserting them into the test fixture. Its contacts will wipe through a film of wax, but they can become clogged and ineffectual if the operator is careless about cleanliness.

5.7.2 Care of the Display Panel.

Use caution when cleaning the display window, not to scratch it nor to get cleaning substances into the instrument. Use soft cloth or a ball of absorbent cotton, moistened with

a mild glass cleaner, such as "Windex" (Drackett Products Co., Cincinnati, Ohio). Do NOT use a paper towel; do NOT use enough liquid to drip or run.

If it should be necessary to place marks on the window, use paper-based masking tape (NOT any kind of marking pen, which could be abrasive or react chemically with the plastic). To minimize retention of any gummy residue, remove the tape within a few weeks.

5.8 TROUBLE ANALYSIS.

5.8.1 General.

CAUTION

Only well qualified personnel should attempt trouble analysis. Be sure power is OFF during disassembly and setting up for tests. Carefully observe the MOS HANDLING PRECAUTIONS given in para 5.6.

Resources. Refer to Section 4 for a good understanding of the theory of operation. The block diagrams and discussion there provide necessary background, which can generally save time in trouble analysis. Refer to Section 6 for hardware details: circuit layouts, schematic diagrams, and parts lists.

Abnormal digital signal levels. Most digital signal levels in this instrument are normally near zero (logic low), about +3.5 to +5 V (logic high), or rapidly switching between these states. Failure of a digital source often produces a dc voltage of about +2 V on a signal line. Use high-impedance probes in measuring. Use a scope as well as a voltmeter, because an average of 2 V may be normal for a digital signal that has a duty cycle near 50%.

Duplicated circuits. Some circuits, as in the display board for example, are duplicated several times. The IC's can usually be exchanged between a faulty circuit and a functional one, to identify a "bad" IC. Notice, also, that the resistor networks D-Z2 . . . D-Z10 are simply compact packages of 220-Ω resistors. If one resistor is open, it is not necessary to replace the entire package. Use a 5% resistor.

Circuit board replacement. Refer to para 5.3 for recommended procedures to obtain replacements.

Telltale symptoms. Scan the following group of symptoms for a preliminary analysis of trouble and suggestions for more detailed procedures if applicable.

Display. A perpetually blank digit or decimal point may be caused by a fault in the directly associated circuit on the display board. (Refer to comments above.)

Pushbutton. Malfunction of any pushbutton may be caused by a fault in the switch or in buffer C-U19.

Range. If one range is nonfunctional, check the corresponding switch (C-S1 . . . S3), source resistor (R102 . . .), and standard resistor (R69 . . .). If range-1 measurements are inaccurate, also check the inverting amplifier in the I– circuit, C-U46 pin 6.

D Error. A large D error on range 3 may be caused by faulty "protection" diodes in the analog front end. Check C-CR12 . . . 23 (a total of 12 diodes).

D Error. If D measurements are accurate at 1 kHz but erroneous at 120 (100) Hz, fault may be in the test signal filter. Check that C-Q2 is on for low frequency, off for 1 kHz. If so, check the test signal. (See below.)

Reactance Error. If R measurements are accurate but C (and L) measurements are not, the test signal source may be at fault. In checking it, as in the following paragraph, verify that the frequency is within ±0.01% of the specified "actual" frequency. (See front of manual.)

Test Signal. To check performance of the test-signal source, use a scope to look at the open-circuit signal at the I+ terminal of the test fixture. This should be an undistorted sine wave at the selected frequency, amplitude about 0.6 V pk-pk (±15%) on each range. If this is correct, skip over para 5.8.3.

Analog Front End. To check the entire analog front end, verify that the signal at C-U44 pin 8 has the characteristics shown in para 5.8.4, step g, while the instrument is measuring a DUT. If this is true for all modes (FREQUENCY, PAR SERIES, R-L/Q-C/D, RANGES), skip to para 5.8.6. Otherwise, check the test signal at the test fixture as outlined above.

Introduction to Detailed Analysis. The following trouble analysis procedures will serve as a guide for localizing a fault to a circuit area. In some cases, a specific component part can be isolated for replacement. In other cases, the problem can be narrowed down only to a circuit board.

Except for the short-cuts indicated above, follow the procedure strictly in the order given, doing the principal steps (a, b, c, d, . . .) until a failure is found. Only then is there any need for the secondary steps, if any are given at the point of failure (aa, ab, ac . . .).

5.8.2 Power Supply.

Check the power supply (V assembly) if there is a massive failure (nothing works) or as a starting procedure in any thorough analysis. Refer to Figure 5-8.

NOTE

If a power transistor (U1, U2, or U3) must be replaced, be sure to spread silicone grease (like Dow Corning compound no. 5) on the surface toward the heat sink. For U1, coat both sides of the insulating washer.

a. Check the output voltages, using a digital voltmeter, with ground reference at V-J1, pin 9 (ribbon cable unplugged), as follows:

Pin 1 = +5 V.
Pin 3 = +5 V.
Pin 5 = −8 V.

b. Make a check similar to step a, with ribbon cable connected, ground reference at right edge of C board, probing C-J1 from below the board. (This checks for overload outside the power supply.)

aa. If trouble is found at step a, check "+5 V" circuit:
At outputs of U1 and U2: +5 V dc (regulated).
At WT1 (inputs of U1 and U2): +10.8 V dc.
Across input to diode bridge (yellow-to-yellow): 10 V rms.
ab. Check "−8 V" circuit:
At output of U3: −8 V dc (regulated).
At input (center terminal) of U3: −13.8 V dc.
Across WT7 to WT8: 11.3 V rms.
ac. Check power-line circuit to primary of transformer V-T1.

5.8.3 Sinewave Generator.

Check the C-board circuits that supply the test signal to the DUT, as follows: (We proceed backward, toward the sinewave generator.)

a. Make the following test setup and pushbutton selections:

DUT: 0.1 μF and 3 kΩ, connected in series.
FREQUENCY: 1 kHz.
PAR SERIES: SERIES.
FUNCTION: C/D.
RANGE: 2.

b. Verify that the signal at test fixture, + side (right hand), is a 1-kHz sine wave, 0.6 V pk-pk. Use an oscilloscope.

c. Verify that this signal changes amplitude as you switch ranges, thus:

RANGE 1, 0.68 V pk-pk;
RANGE 3, 20 mV pk-pk.

ca. If this signal is distorted or missing on all ranges, but present at the right end of R103, check diode network C-CR16 . . . CR23. If missing on some ranges(s), check source resistor circuit R101 . . . R103 and switches S1 . . . S3.

d. If no fault appears in steps a, b, c, skip to para 5.8.4.

e. Verify that "0.25 V RMS TEST SIGNAL" found at S03 pin 14 is a 1-kHz sine wave, approx 0.6 V pk-pk. (±15%). This is the output from U41 pin 6.

f. Check at U41 pin 3 (the pin closest to the front) for a 1-kHz sine wave, 0.4 V pk-pk.

fa. Check at U45 pin 10 for a 1-kHz sine wave, 60 mV pk-pk. If this is verified but step e is not, fault is in U41.

g. Verify that the output of U18 found at S03 pin 5 is a 1-kHz sine wave, 0.8 V pk-pk. (It is rather noisy, as sketched on the schematic diagram, Figure 6-5.)

h. Remove U18. Connect a 200-Ω resistor across its socket (XU18) between pins 2 and 3. (Note: if the resistor leads are about 0.5 mm [0.02 in.] in diameter,

they will fit the socket directly.) Check at U12 pin 4 for a 1-kHz noisy sine wave, 0.4 V pk-pk. If this is verified but step g is not, fault is in U18. If neither is verified, reinstall U18 and continue.

i. Check that each input to the D/A converter U12 (pins 5 . . . 12), is a digital signal, about 4 V pk-pk. Each of these 8 signals should repeat with a period of 1 ms.

If these digital signals are NOT correct, continue the analysis by checking the crystal oscillator and divider chain, as follows.

NOTE

Dual specifications of frequency appear below. The first frequency is correct for 1657-9700 (the 120-Hz version). The second is correct for 1657-9800 (the 100-Hz version). Frequency tolerance is ±0.01%.

j. Make the following test setup. Connect from the scope vertical-channel output to a counter. Be sure to use a low-capacitance probe at the scope input, so as not to load the high-impedance circuits being analyzed.

k. Oscillator. Check at U8 pin 14 for a fast digital waveform (see schematic diagram) of the following frequency: 25.067 or 24.576 ±0.003 MHz. If correct, skip to step 1. (This circuit is easily loaded down by test equipment. A more "tolerant" point is checked in step l.)

l. Check at U8 pin 8 for a square wave, 4 V pk-pk, 2.0889 or 2.0480 MHz. Otherwise, U8 is faulty.

m. Check at U9, pins 1, 9, 8 for pulses (essentially rectangular, as shown on the schematic diagram), with frequencies as follows:

Pin 1, 1.0445 or 1.0240 MHz.
Pin 9, 522.24 or 512.00 kHz.
Pin 8, 261.12 or 256.00 kHz.

Otherwise, U9 is faulty.

n. Check at U10, pins 12, 9, 5 for similar pulses, as shown, with frequencies as follows:

Pin 12, 276. or 261.12 kHz.
Pin 9, 61.440 or 78.3 kHz.
Pin 5, 30.720 or 26.112 kHz.

Otherwise, U10 is faulty.

NOTE

At pin 12, for the 1657-9700, every 9th square wave is half the regular width; at pin 9, for the 1657-9800, every 3rd positive pulse is only about 1 μs wide; therefore the counter reading may vary somewhat, depending on the length of its counting interval.

o. Check at U14 pin 2 for square waves, 5 V pk-pk, at 261.12 or 256.00 kHz.

ia. If these inputs are verified but step h is not, fault is in U12 circuit. Check at the end of R16 closest to the rear corner for +3 V dc; if that is correct, replace U12. Otherwise, fault is in associated circuit.

ka. If oscillator signal is not verified, remove U8 from its socket and repeat step k. (Check at U13 pin 13, if convenient.) If signal is now normal, U8 is faulty. Otherwise, install U8 and determine whether your instrument has a self-contained oscillator or a separate crystal Y1.

kb. If your instrument has a separate crystal, remove it and repeat step k. The correct frequency is approx 31.2 MHz (either 120- or 100-Hz version). If this is verified, Y1 is faulty. Otherwise, install Y1 and check at U7 pins 2, 3, 11 for voltages of +4, +3, +4.2V, respectively. If they are correct, U7 is faulty.

kc. If your instrument has the self-contained oscillator, failure in steps k and ka indicates the oscillator U7 is faulty.

oa. If step o is not confirmed, be sure you have selected 1 kHz on the front panel. Check that FREQ SEL (U15 pin 8) is logic high and $\overline{\text{FREQ SEL}}$ (pin 6) is low. (Otherwise check back through U24, U19, and S8.)

ob. If those checks are confirmed, fault is in the gates U15 pins 4, 10, 3 or U14 pin 2.

p. While monitoring U14 pin 2, push the FREQUENCY pushbutton and select 120 Hz, (or 100 Hz). Check that the monitored signal (which should always be 256 times the test frequency) is now 30720 Hz or 25600 Hz. Again push the FREQUENCY button to select "1 kHz."

q. Check that the outputs of U16 are square waves, 5 V pk-pk, frequencies as follows (for 1657-9700 or 1657-9800 respectively):

Pin 12, 130.56 or 128.00 kHz.
Pin 9, 65.28 or 64.00 kHz.
Pin 8, 32.64 or 32.00 kHz.
Pin 11, 16.320 or 16.00 kHz.

Otherwise, U16 is faulty.

r. Check U17 similarly:

Pin 12, 8.160 or 8.000 kHz.
Pin 9, 4.080 or 4.000 kHz.
Pin 8, 2.040 or 2.000 kHz.
Pin 11, 1.0200 or 1.0000 kHz.

Otherwise U17 is faulty.

s. If inputs to the sine rom U11 are valid (steps j . . . r) but its output is not (steps a . . . i), U11 is faulty; or possibly (because step i does not check the output code from U11) U12 may be faulty. They can be checked against their manufacturer's data sheets.

5.8.4 Front End Amplifiers and Switches.

Check the C-board analog circuits that process the measurement signals from the test fixture to the point of A/D conversion, as follows:

a. Verify that there is a normal test signal at the test fixture. (See para 5.8.1 or para 5.8.3 step b.)

b. Make the setup of para 5.8.3, step a. Measure using a low-capacitance probe with an oscilloscope. (The frequency counter is not needed.)

c. Check at U43 pin 1 for 1-kHz sine wave, 500 mV pk-pk. Check at U43 pin 8 for a similar waveform, 150 mV pk-pk.

d. Check at switch U39 pin 3, using the gate signal SSW1 (U39 pin 5) as a trigger for your scope. Pin 3 should be a 1-kHz switched sine wave, 500 mV pk-pk for a few cycles, while SSW1 is logic high.

e. Similarly, check at switch U39 pin 10, using the gate signal SSW2 (U39 pin 12) as trigger. The signal at pin 10 should be a switched 1-kHz sine wave, 150 mV pk-pk for a few cycles, while SSW2 is logic high.

f. Return the scope to automatic triggering. Check at the buffer U44 pin 1 for a 1-kHz sine wave that steps repeatedly between 2 levels. The larger level should be 4 V pk-pk; the smaller, 1.2 V pk-pk.

g. Check at the integrator U44 pin 8 or the equivalent test point S03 pin 1 for the waveform shown in Figure 5-9. Notice that the staircases each have 17 steps or 20 steps (for 1657-9700 and -9800, respectively) for 1 kHz but only 2 steps if you select 120 Hz (100 Hz).

ca. Otherwise, check the associated amplifier U46 pin 6 for a similar waveform, 160 mV pk-pk. If this is not right, fault may be in U46/U42 circuit; if right, fault is in U43 circuitry.

da. If step d is not confirmed, or if the triggering fails, check SSW1 at pin 5. It should be a slow rectangular wave, (approx 3 Hz), switching between approx +5 V and −8 V. Otherwise, check U33 and U24; refer to para 5.8.5. If SSW1 is correct, U39 is faulty.

ea. Otherwise, or if the triggering fails, check SSW2 at pin 12. It should be a slow rectangular wave, (approx 3 Hz), from +5 V to −8 V. Otherwise, check U33 and U24; also refer to para 5.8.5. If SSW2 is correct, U39 is faulty.

fa. Otherwise, confirm that the input to this stage is correct by checking at S03 pin 3 for sine wave that steps between 2 levels: 500 mV and 150 mV pk-pk. If this is correct, U44 is faulty.

Also, the amplitudes of the staircases depend on the RANGE selected and the impedance components of the DUT. The chosen conditions make 1 staircase taller than the other 7; so the waveform can be "stopped", by careful setting of scope sweep trigger adjustment. (Preferably, trigger on the positive slope, at a low voltage.)

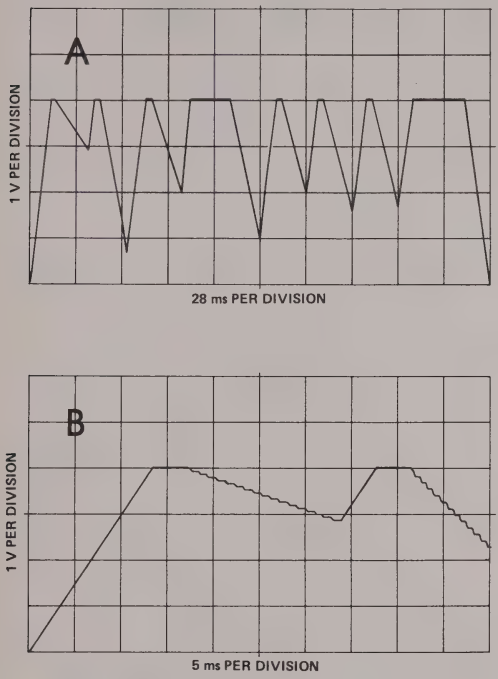

Figure 5-9. Integrator output waveform for the conditions of para 5.8.4. The full waveform is shown in A. It repeats at least 3 times per second, and includes 8 staircases, for a complete measurement cycle. The expansion, B, shows typical detail in the first 2 staircases. Each staircase has 17 steps for 1 kHz, 2 for 120 Hz in the 1657-9700 (20 for 1 kHz, 2 for 100 Hz in the 1657-9800).

h. Check at the comparator output U44 pin 14 or test point S03 pin 2 for CMP, a positive pulse (+5 V) on a base line about −5 V dc. Otherwise, U44 is faulty.

i. If a nonfunctional instrument passes all the preceding checks, i.e., no fault can be found in the analog circuitry, the fault is liable to be in digital circuitry. See below.

5.8.5 Control Signal Checks. Figures 5-10, 5-11.

If there is no staircase waveform at the integrator output (U44 pin 8), as described above, the following procedure is recommended to determine whether the fault is in the digital control circuitry.

ga. If step g is not verified, check at the switch control terminals U40 pins 5, 6, 12, 13 for the presence of digital signals with logic high and low levels of +5 V and −8 V.

If all of these signals are present, either U40 or U44 is faulty; replace both of them. Otherwise, check U33 and U34. Also refer to para 5.8.5.

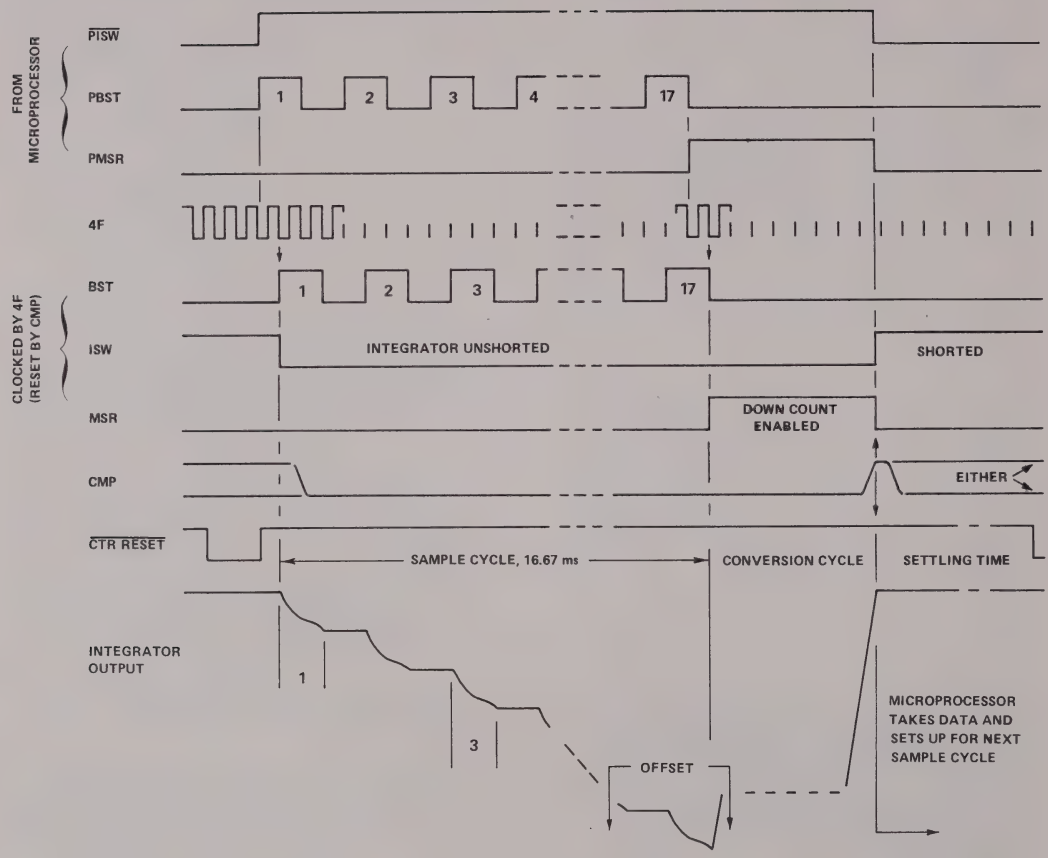

Figure 5-10. Timing diagram. One complete staircase cycle for a typical 1-kHz measurement on a 1657-9700. The 3 main divisions are: sample cycle (stair steps down), conversion cycle (smooth ramp up, during which a counter arrives at digital value of signal being sampled), and data-taking cycle (microprocessor takes data and sets up for next staircase). In this example, there are 17 samples taken.

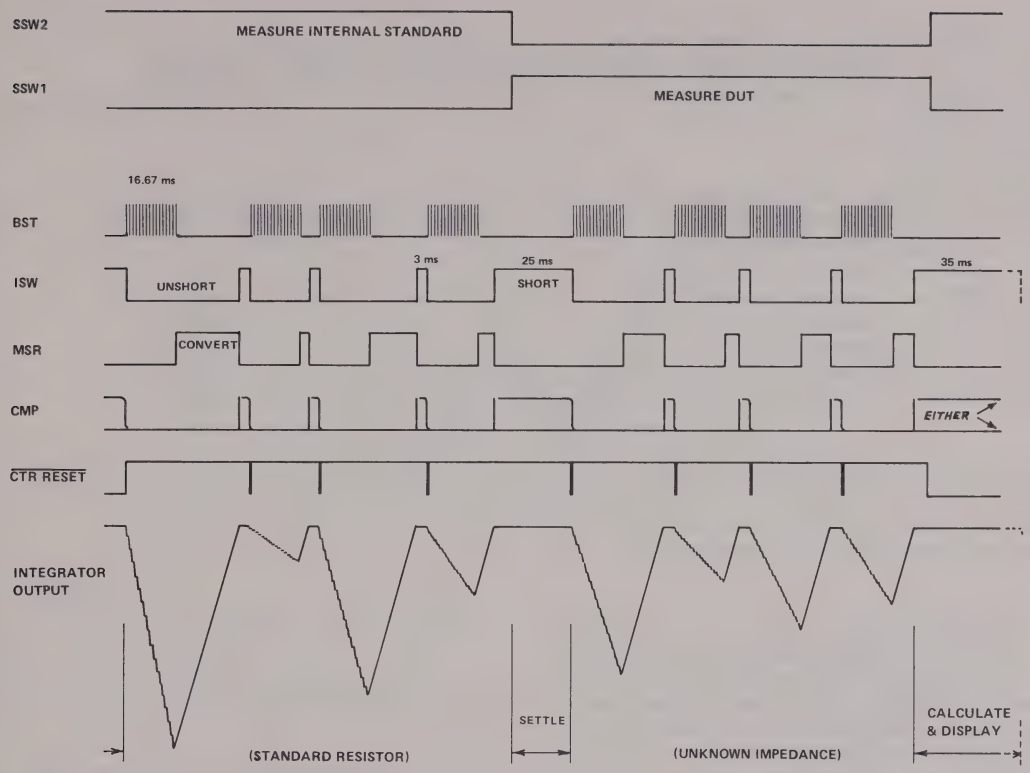

Figure 5-11. Timing diagram. One complete measurement cycle for a typical 1-kHz measurement on a 1657-9700. There are always 8 staircase cycles, one with each phase of BST for the signal from the standard (via U43 pin 8) and one with each phase of BST for the signal from the DUT (via U43 pin 1). The CMP pulses can take either a short or a long form (either is correct); the short ones are logic high for a fraction of a millisecond; the long ones are similar to ISW, but less sharp.

a. Look at the following control signals with a scope and compare them with the timing diagram:

PBST, at C-U33 pin 10;

PMSR, at U33 pin 12.

If they are normal, skip to step b. If they are inactive, perhaps they can be stimulated by applying pulses to the power-on reset circuit; see step aa.

b. Examine each of the following digital feedback signals and compare it with the timing diagram. If any one is questionable, check the circuit from which it is derived; F, 2F, and 4F, at U4 pins 2, 4, and 6 (from U17); DMSR, at U4 pin 10 (from PMSR via U33 and U34); $\overline{\text{DONE}}$, at U25 pin 1 (from $\overline{\text{RES}}$ via U29 and U35).

Notice that $\overline{\text{DONE}}$ would echo CMP if the latter were provided as usual, by the integrator and comparator, U44. Otherwise, $\overline{\text{DONE}}$ echoes the reset pulse provided in step aa.

aa. Provide reset pulses in either of 2 ways. Preferably, set up a pulse generator as follows:
Source resistance: 50 Ω.
Repetition rate (period): 1 s.
Pulse polarity and duration: positive, 0.5 s.
Dc levels: high = 4.5 V; low = 0 V.
Connect from ground to: U6 pin 13.

ab. The alternative method is to short across C5 momentarily (and repeatedly) with a clip lead. Watch the scope carefully for activation, perhaps for only 1 cycle, of PBST and/or PMSR, after each application of the short circuit. Notice that this short must be only momentary and that it must not be applied while the pulse generator is connected. Find C5 at the rear edge of the C board, nearest Q1, which is between U6 and U7.

ac. If PBST and PMSR remain inactive in spite of the preceding stimulation, the digital control circuitry is at fault: go to para 5.8.6. Otherwise, proceed to step b, continuing to use the reset pulses.

c. If the feedback signals are present, look at each of the following control signals and compare it with the timing diagram: (The first 4 signals have logic low and high levels of 0 and +5 V; the last 8 signals, −8 and +5 V.)
PBST, at U33 pin 10;
PMSR, at U33 pin 12;
$\overline{\text{PISW}}$, at U33 pin 8;
$\overline{\text{RES}}$, at U29 pin 8 (reset, normally only at power turn-on);
SSW1, at U39 pin 5 (from PSSW1, at U33 pin 6);
SSW2, at U39 pin 12 (from PSSW2, at U33 pin 2);
Clock at U34 pin 9 (from 4F, at U29 pin 6);
Reset at U34 pin 1 (from same sources as $\overline{\text{DONE}}$);
BST, at U40 pin 13 (clocked by 4F, enabled by PBST);
$\overline{\text{BST}}$, at U40 pin 5 (complement of BST);
MSR at U40 pin 6 (clocked by 4F, enabled by PMSR);
ISW, at U40 pin 12 (clocked by 4F, enabled by $\overline{\text{PISW}}$).

If any is abnormal, trace back to the source of the signal, with the help of the schematic diagram (to check for poor connections or other interface problems). If the source is faulty, go to para 5.8.6. If these control signals are all valid, the fault is probably in the integrator U44 or associated circuits.

5.8.6 Digital Circuitry.

Display Board. A faulty integrated-circuit package can usually be identified by interchanging plug-in component parts of the same type between display channels. Notice that a resistor network need NOT be replaced as a unit; use ordinary resistors. (See para 5.8.1.)

Recommended Procedure. If careful analysis of a faulty instrument, using the preceding information, indicates that the trouble is in the digital circuitry (whether in control, computation, or display decoding), further analysis is beyond the scope of this manual. Return the faulty board (the C board, if the fault is digital, and not in the display board) or return the instrument for service. Refer to para 5.2 and 5.3.

Special Testing. Because of the very high speed and considerable complexity of the C-board digital circuitry, it is impossible to analyze trouble there with ordinary test equipment. GenRad production and in-factory service departments make use of fast, versatile automatic test systems (GR products). Their efficiency and accuracy are important factors in our recommendation that digital circuit problems be solved by exchanging boards.

Parts Lists and Diagrams—Section 6

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6.1 GENERAL.

This section contains the parts lists, circuit-board layout drawings and schematic diagrams for the instrument. (Section 4 contains functional block diagrams. Section 5 contains photographs of the instrument, identifying various parts.) The heavy lines on schematic diagrams denote the major signal flow.

Reference designation usage is described below.

6.2 REFERENCE DESIGNATIONS.

Each electrical component part on an assembly is identified on equipment and drawings by means of a reference designator comprised of numbers and letters. Component types on an assembly are numbered sequentially, the numbers being preceeded by a letter designation that identifies the component (R for resistor, C for capacitor, etc.). Some of the less obvious designators are: DS, lamp; Q, transistor; U, integrated circuit; WT, wire tie point; X, J, P, or SO, connector; Y, crystal resonator; Z, filter or network.

Each assembly (typically a circuit board) has its own sequence of designators which can be identified by using prefixes, such as A- for the main frame and V- for power supply. Examples: B-R8 designates B board, resistor 8; D-WT2 = D board, wire-tie point 2; CR6 on the V schematic is a shortened form of designator V-CR6 = V board, diode 6. The instrument may contain A-R1, B-R1, C-R1, and D-R1.

6.3 DIAGRAMS.

Generally, each schematic diagram is located on a right-hand fold-out page for convenience. The associated layout drawing and parts list are located on the same page, the facing page, or otherwise nearby.

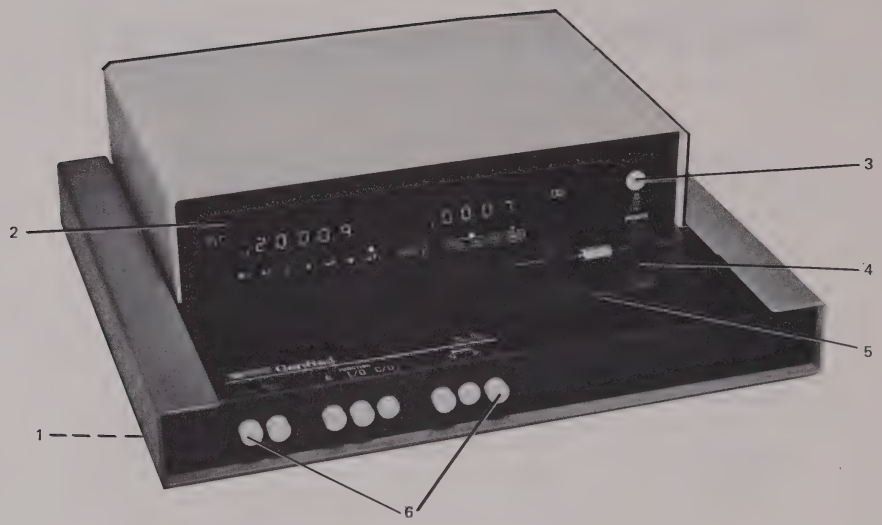

Figure 6-1. Front view showing mechanical replaceable parts.

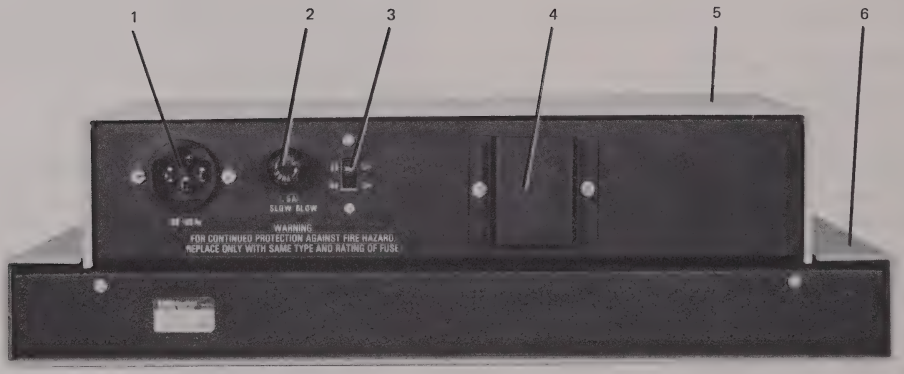

Figure 6-2. Rear view showing mechanical replaceable parts.

MECHANICAL PARTS LIST

FRONT VIEW

FIG REF	QUANTITY	DESCRIPTION	GR PART NO.	FMC NO.	MFGR PART NO.
1	4	FOOT, SOFT	5260-2051	24655	5260-2051
2	1	DISPLAY PANEL (120 Hz)	1657-7001	24655	1657-7001
	(OR)	DISPLAY PANEL (100 Hz)	1657-7002	24655	1657-7002
3	1	ACTUATOR (PUSH ROD)	1657-2810	24655	1657-2810
4	2	ADAPTOR (FOR AXIAL LEAD DUT)	1657-1910	24655	1657-1910
5	1	TEST-FIXTURE GUIDE BLOCK	1657-2200	24655	1657-2200
6	8	PUSH BUTTON CAP	5511-0450	71590	B-315 WT

REAR VIEW

1	1	CONNECTOR, POWER, J1	4240-0210	24655	4240-0210
2	1	POST, FUSE EXTRACTOR, F1	5650-0100	75915	342-004
3	1	SWITCH, SLIDE, S2	7910-0832	82389	11A-1266
4	1	COVER	1657-8120	24655	1657-8120
5	1	TOP COVER	1657-8060	24655	1657-8060
6	1	BOTTOM SHELL	1657-8000	24655	1657-8000

FEDERAL MANUFACTURER'S CODE

From Federal Supply Code for Manufacturers Cataloging Handbooks H4-1
(Name to Code) and H4-2 (Code to Name) as supplemented through August, 1968.

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00656	Aerovox Corp., New Bedford, MA 02745
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02114	Ferroxcube Corp., Saugerties, NY 12477
02606	Fenwal Lab Inc., Morton Grove, IL 60053
02660	Amphenol Electron Corp., Broadview, IL 60153
02768	Fastex, Des Plains, IL 60016
03042	Carter Ink Co., Cambridge, MA 02142
03508	G. E. Semicon Prod., Syracuse, NY 13201
03636	Grayburne, Yonkers, NY 10701
03877	Transitron Electronics, Wakefield, MA 01880
03911	Clairex Corp., New York, NY 10001
04009	Arrow Hart, Hartford, CT 06106
04643	Digitronics Corp., Albertson, NY 11507
04713	Motorola, Phoenix, AZ 85008
04919	Component Mfg. Service, Inc., West Bridgewater, MA 02379
05079	Tansitor Electronics, Bennington, VT 05201
05402	Controls Co. of America, Melrose Park, IL 60160
05574	Viking Industries, Inc., Chatsworth, CA 91311
05624	Barber-Colman Co., Rockford, IL 61101
05748	Barnes Mfg. Co., Mansfield, OH 44901
05820	Wakefield Engineering Inc., Wakefield, MA 01880
06743	Clevite Corp., Cleveland, OH 44110
07126	Digitran Co., Pasadena, CA 91105
07127	Eagle Signal (E.W. Bliss Co.), Baraboo, WI 53913
07233	Cinch Graphik, City of Industry, CA 91744
07261	Avnet Corp., Culver City, CA 90230
07263	Fairchild Semiconductor, Mountain View, CA 94040
07387	Birtcher Corp., No. Los Angeles, CA 90032
07595	Amer. Semiconductor, Arlington Hts, IL 60004
07828	Bodine Corp., Bridgeport, CT 06606
07829	Bodine Electric Co., Chicago, IL 60618
07910	Cont. Device Corp., Hawthorne, CA 90250
07983	State Labs, Inc., New York, NY 10003
07999	Borg Instruments, Delavan, WI 53115
08730	Vemaline Products Co., Franklin Lakes, NJ 07417
09213	G. E. Semiconductor, Buffalo, NY 14207
09353	C & K Components Inc., Watertown, MA 02172
09408	Star-Tronics Inc., Georgetown, MA 01830
09823	Burgess Battery Co., Freeport, IL 61032
09856	Fenwal Electronics, Inc., Framingham, MA 01701
09922	Burndy Corp., Norwalk, CT 06852
11236	CTS of Berne, Inc., Berne, IN 46711
11599	Chandler Evans Corp.,W. Hartford, CT 06101
11983	Nortronics Co., Inc., Minneapolis, MN 55427
12040	National Semiconductor, Santa Clara, CA 95051
12045	Electronic Transistors Corp., Flushing, NY 11354
12498	Teledyne Semiconductor, Mountain View, CA 94043
12617	Hamlin, Inc., Lake Millis, WI 53551
12872	R. C. A., Woodridge, NJ 07095
12697	Clarostat Mfg. Co., Inc., Dover, NH 03820
12954	Dickson Electronics Corp., Scottsdale, AZ 85252
12969	Unitrode Corp., Watertown, MA 02172
13094	Electrocraft Corp., Hopkins, MN 55343
13103	Thermalloy, Inc., Dallas, TX 75234
13327	Solitron Devices, Tappan, NY 10983
13919	Burr Brown Research Corp., Tucson, AZ 85706
14195	Electronic Controls, Inc., Wilton, CT 06897
14433	I.T.T. Semiconductors, W. Palm Beach, FL 33402
14482	Watkins & Johnson Co., Palo Alto, CA 94304
14655	Cornell Dubilier Electronics, Newark, NJ 07101
14674	Corning Glass Works, Corning, NY 14830
14749	Acopian, Easton, PA 18042
14752	Electro Cube, Inc., San Gabriel, CA 91776
14936	General Instrument Corp., Hicksville, NY 11802
15116	Microdot Magnetics, Inc., Los Angeles, CA 90053
15238	I.T.T. Semiconductors, Lawrence, MA 08142
15476	Digital Equipment Corp., Maynard, MA 01754
15605	Cutler Hammer, Inc., Milwaukee, WI 53202
15782	Houston Instrument Corp., Bellaire, TX 77401
16037	Spruce Pine Mica Co., Spruce Pine, NC 28777
16179	Omni Spectra Mich Div., Farmington, MI 48024
16352	Computer Diode Corp., Lodi, NJ 07644
16636	Indiana General Corp., Oglesby, IL 61348
16758	Delco Electronic Div., GMC, Kokomo, IN 46901
16950	Precision Dynamics Corp., Burbank, CA 91504
16952	American Micro Devices, Inc., Summerville, SC 29483
17117	Electronic Molding Corp., Woonsocket, RI 02895
17771	Singer Co., Diehl Div., Somerville, NJ 08876
17850	Zeltex, Inc., Concord, CA 94520
17856	Siliconix, Inc., Santa Clara, CA 95054
18324	Signetics, Corp., Sunnyvale, CA 94086
18542	New Product Engineering Inc., Wabash, IN 46992
18677	Scanbe Manufacturing Corp., El Monte, CA 91731
18736	Voltronics Corp., Hanover, NJ 07936
18736	Computer Diode Corp., S. Fairlawn, NJ 07936
19048	Computer Diode Corp., S. Fairlawn, NJ 07410
19178	Zero Manufacturing Co., Monson, MA 01057
19373	Eastron Corp., Haverhill, MA 01830
19396	Illinois Tool Works, Pakton Div., Chicago, IL 60634
19617	Cabtron Corp., Chicago, IL 60622
19644	L.R.C. Electronics, Horseheads, NY 14845
19701	Electra Mfg. Co., Independence, KS 67301
20754	K.M.C. Semiconductor, Long Valley, NJ 07853
21335	Fafnir Bearing Co., New Britain, CT 06050
21759	Lenox-Fugle Electronics, Watchung, NJ 07060
22753	UID Electronics Div., AMF Inc., Hollywood, FL 33022
23338	Wavetek Div., John Fluke, San Diego, CA 92112
23342	Avnet Electronics Corp., Franklin Park, IL 60131
24355	Analog Devices, Cambridge, MA 02142
24446	General Electric, Schenectady, NY 12305
24454	General Electric Electronics Comp., Syracuse, NY 13201
24455	General Electric Lamp Div., Cleveland, OH 44112
24602	E.M.C. Technology, Cherry Hill, NJ 08034
24655	General Radio Co., Concord, MA 01742
25289	E. G. & G. Inc., Bedford, MA 01730
26806	American Zettler, Inc., Costa Mesa, CA 92626
26480	Hewlett Packard, Palo Alto, CA 04304
28520	Heyman Mfg. Co., Kenilworth, NJ 07033
28959	Hoffman Electronics Corp., El Monte, CA 91734
30646	Beckman Instruments, Inc., Cedar Grove, NJ 07009
30874	I.B.M., Armonk, NY 10504
32001	Jensen Mfg. Co., Chicago, IL 60638
33173	General Electric Comp., Owensboro, KY 42301
34141	Koehler Mfg. Co., Inc., Marlboro, MA 01752
35929	Constanta, Co., Montreal Quebec
37942	P. R. Mallory & Co., Inc., Indianapolis, IN 46206
38443	Marlin-Rockwell Corp., Jamestown, NY 14701
39317	McGill Manufacturing Co., Inc., Valparaiso, IN 46383
40931	Honeywell, Inc., Minneapolis, MN 55408
42190	Muter Co., Chicago, IL 60638
42498	National Co., Inc., Melrose, MA 02176
43991	Norma Hoffman, Stanford, CT 06904
49671	R. C.A., New York, NY 10020
49956	Raytheon Mfg. Co., Waltham, MA 02154
50088	Mostek, Carrollton, TX 75006
53021	Sangamo Electric Co., Springfield, IL 62705
54294	Shallcross Mfg. Co., Selma, NC 27576
54715	Shure Brothers, Inc., Evanston, IL 60202
56289	Sprague Electric Co., North Adams, MA 01247
59730	Thomas & Betts Co., Elizabeth, NJ 07207
59875	T.R.W. Inc., (Accessories Div), Cleveland, OH 44117
60399	Torrington Mfg. Co., Torrington, CT 06790
61637	Union Carbide Corp., New York, NY 10017
61864	United-Carr Fastener Corp., Boston, MA 02142
63060	Victoreen Instrument Co., Cleveland, OH 44104
63743	Ward Leonard Electric, Mt. Vernon, NY 10550
65083	Westinghouse (Lamp Div), Bloomfield, NJ 07003
65092	Weston Instruments, Newark, NJ 07114
70106	Acushnet Capacitor Co., New Bedford, MA 02742
70109	Adams and Westlake Co., Elkhart, IN 46514
70485	Atlantic India Rubber Works, Inc., Chicago, IL 60607
70563	Amperite Co., Union City, NJ 07087
70903	Belden Mfg. Co., Chicago, IL 60644
71126	Bronson Homer D., Beacon Falls, CT 06403
71279	Cambridge Thermionic, Corp., Cambridge, MA 02138
71294	Canfield Co., Clifton Forge, VA 24422
71400	Bussmann Mfg. Co., St. Louis, MO 63107
71450	CTS Corp., Elkhart, IN 46514
71468	ITT-Cannon Electric Inc., Los Angeles, CA 90031
71482	C.P. Clare & Co., Chicago, IL 60645
71590	Centralab, Inc., Milwaukee, WI 53212
71666	Continental Carbon Co., Inc., New York, NY 10001
71707	Coto Coil Co., Inc., Providence, RI 02905
71729	Crescent Box Corp., E. Philadelphia, PA 19134
71744	Chicago Miniature Lamp., Chicago, IL 60640
71785	Cinch Jones, Chicago, IL 60624
71823	Darnell Corp., Ltd., Downey, CA 90241
72136	Electromotive Mfg. Co., Willimantic, CT 06226
72228	Continental Screw Co., New Bedford, MA 02742
72259	Nytronics, Inc., Berkeley Hts, NJ 07922
72619	Dialight Co., Brooklyn, NY 11237
72699	General Instrument Corp., Newark, NJ 07104
72765	Drake Mfg. Co., Chicago, IL 60631
72794	Dzus Fastener Co., Inc., West Islip, NY 11795
72825	Eby Co., Hugh H, Philadelphia, PA 19144
72962	Elastic Stop Nut Corp., Union, NJ 07083
72982	Erie Technological Products, Erie, PA 16512
73445	Amperex Electronic Corp., Hicksville, LI, NY 11801
73559	Carling Electric Co., W. Hartford, CT 06110
73690	Elco Resistor Co., New York, NY 10001
73899	J.F.D. Electronics Corp., Brooklyn, NY 11219
73957	Groov-Pin Corp., Ridgefield, NJ 07657
74193	Heinemann Electric Co., Trenton, NJ 08602
74545	Hubbell, Stratford, CT 06497
74861	Industrial Condenser Corp., Chicago, IL 60618
74868	Amphenol RF Division, Danbury, CT 06810
74970	Johnson Co., E.F., Waseca, MN 56093
75042	IRC Div. of TRW, Burlington, IA 52601
75382	Kulka Electric Corp., Mt. Vernon, NY 10551
75491	Lafayette Industrial Electronics, Syosset, NY 11791
75608	Linden & Co., Providence, RI 02905
75915	Littelfuse, Inc., Des Plaines, IL 60016
76005	Lord Mfg. Co., Erie, PA 16512
76149	Mallory Electric Corp., Detroit, MI 48204
76381	Minnesota Mining., St. Paul, MN 55101
76487	Millen Mfg. Co., Inc., Malden, MA 02148
76545	Mueller Electric Co., Cleveland, OH 44114
76684	National Tube Co., Pittsburg, PA 15230
76854	Oak Mfg. Co., Crystal Lake, IL 60014
77147	Patton MacGuyer Co., Providence, RI 02905
77166	Pass-Seymour, Syracuse, NY 13209
77263	Pierce-Roberts Rubber Co., Trenton, NJ 08638
77339	Positive Locknasher Co., Newark, NJ 07101
77342	American Machine & Foundry Co., Princeton, IN 47570
77542	Ray-O-Vac Co., Madison, WI 53703
77630	T.R.W. Electronic Comp., Camden, NJ 08103
77638	General Instruments Corp., Brooklyn, NY 11211
78189	Shakeproof (Ill. Tool Wks), Elgin, IL 60120
78277	Sigma Instruments Inc., South Braintree, MA 02184
78488	Stackpole Carbon Co., St. Mary's, PA 15827
78553	Tinnerman Products, Inc., Cleveland, OH 44101
79089	R.C.A. Rec. Tube & Semicond., Harrison, NJ 07029
79136	Waldes Kohinoor Co., New York, NY 11101
79725	Wiremold Co., Hartford, CT 06110
79727	Continental WIRT Electronics Corp., Philadelphia, PA 19101
79963	Zierick Mfg. Co., Mount Kisco, NY 10549
80009	Tektronix, Inc., Beaverton, OR 97005
80030	Prestole Fastener, Toledo, OH 43605
80048	Vickers Inc., St. Louis, MO 63166
80103	Lambda Electronics Corp., Melville, NY 11746
80183	Sprague Products Co., North Adams, MA 01247
80211	Motorola Inc., Franklin Park, IL 60131
80251	Formica Corp., Cincinnati, OH 45232
80258	Standard Oil Co., Lafeyette, IN 47902
80294	Bourns Laboratories, Inc., Riverside, CA 92506
80368	Sylvania Electric Products, Inc., New York, NY 10017
80431	Air Filter Corp., Milwaukee, WI 53218
80583	Hammarlund Co., Inc., New York, NY 10010
80694	Pure Carbon Co., St. Mary's, PA 15857
81030	International Instrument, Orange, CT 06477
81073	Grayhill Inc., LaGrange, IL 60525
81143	Isolantite Mfg. Corp., Stirling, NJ 07980
81312	Winchester Electronics Co., Inc., Oakville, CT 06779
81349	Military Specifications
81350	Joint Army-Navy Specifications
81483	International Rectifier Corp., El Segundo, CA 90245
81751	Columbus Electronics Corp., Yonkers, NY 10701
81831	Filtron Co., Flushing, NY 11354
81860	Barry Wright Corp., Watertown, MA 02172
82219	Sylvenia Elec. Prod., Emporium, PA 15834
82273	Indiana Pattern & Model Works, LaPort, IN 46350
82389	Switchcraft, Inc., Chicago, IL 60630
82647	Metals & Controls, Inc., Attleboro, MA 02703
82807	Milwaukee Resistor Co., Milwaukee, WI 53204
82877	Rotron Mfg. Co., Inc., Woodstock, NY 12498
83003	Varo Semiconductor Div., Garland, TX 75040
83033	Meissner Mfg., Mt. Carmel, IL 62863
83058	Carr Fastener Co., Cambridge, MA 02142
83186	Victory Engineering, Springfield, NJ 07081
83361	Bearing Specialty Co., San Francisco, CA 94101
83587	Solar Electric Corp., Warren, PA 16365
83594	Burroughs Corp., Plainfield, NJ 07061
83740	Union Carbide Corp., New York, NY 10017
84411	TRW Capacitor Division, Ogallala, NB 69153
84835	Lehigh Metal Products, Cambridge, MA 02140
84970	Sarkes Tarzian, Inc., Bloomington, IN 47401
84971	T.A. Mfg. Corp., Los Angeles, CA 90039
86577	Precision Metal Products, Stoneham, MA 02180
86684	R.C.A. (Elec. Comp. & Dev), Harrison, NJ 07029
86687	R.E.C. Corp., New Rochelle, NY 10801
86800	Cont. Electronics Corp., Brooklyn, NY 11222
88140	Cutler-Hammer Inc., Lincoln, IL 62656
88219	Gould Nat. Batteries, Inc., Trenton, NJ 08607
88419	Cornell Dubilier, Fuquay-Varina, NC 27526
88627	K & G Mfg. Co., New York, NY 10001
89462	Holtzer Cabot Corp., Boston, MA 02119
89665	United Transformer Co., Chicago, IL 60607
89870	Berkshire Transformer Corp., Kent, CT 06757
90201	Mallory Capacitor Co., Indianapolis, IN 46206
90303	Mallory Battery Co., Tarrytown, NY 10591
90634	Gulton Industries, Inc., Metuchen, NJ 08840
90750	Westinghouse Electric Corp., Boston, MA 02118
90952	Hardware Products Co., Pennsauken, PA 19602
91032	Continental Wire Corp., York, PA 17405
91146	I.T.T. (Cannon), Salem, MA 01970
91210	Gerber Mfg. Co., Mishawaka, IN 46544
91293	Johanson Mfg. Co., Boonton, NJ 07005
91417	Harris Semiconductor, Melbourne, FL 32901
91506	Augat Brothers, Inc., Attleboro, MA 02703
91598	Chandler Co., Wethersfield, CT 06109
91637	Dale Electronics, Inc., Columbus, NE 68601
91662	Elco Corp., Willow Grove, PA 19090
91719	General Instruments Corp., Dallas, TX 75220
91836	Kings Electronics, Co., Inc., Tuckahoe, NY 11223
91916	Mephisto Tool Co., Inc., Hudson, NY 12534
91929	Honeywell, Inc., Freeport, IL 61032
92519	Electra Insul. Corp., Woodside, LI., NY 11377
92678	Edgerton Germeshausen, Georgetown, MA 01830
92702	I.M.C. Magnetics Corp., Westbury, NY 11591
92739	Ampex Corp., Redwood City, CA 94063
92966	Hudson Lamp Co., Kearny, NJ 07032
93332	Sylvania Elect. Prods., Inc., Woburn, MA 01801
93618	R & C Mfg. Co. of Penn, Inc., Ramsey, PA 16671
93916	Cramer Products Co., New York, NY 10013
94144	Raytheon Co., Components Div., Quincy, MA 02169
94154	Tung Sol Electric Inc., Newark, NJ 07101
94271	Weston Instruments, Inc., Archibald, PA 18403
94322	Tel Labs, Manchester, NH 03103
94589	Dickson Co., Chicago, IL 60619
94696	Magnecraft Electric Co., Chicago, IL 60630
94800	Atlas Industrial Corp., Brookline, NH 03033
95076	Garde Mfg. Co., Cumberland, RI 02864
95121	Quality Components, Inc., St. Marys, PA 15857
95146	Alco Electronics Mfg. Co., Lawrence, MA 01843
95238	Continental Connector Corp., Woodside, NY 11377
95275	Vitramon, Inc., Bridgeport, CT 06601
95348	Gordos Corp., Bloomfield, NJ 07003
95354	Methode Mfg. Co., Rolling Meadow, IL 60008
95794	American Brass Co., Torrington, CT 06790
95987	Weckesser Co., Inc., Chicago, IL 60646
96095	Hi Q Division of Aerovox Corp., Olean, NY 14760
96341	Microwave Associates, Inc., Burlington, MA 01801
96906	Military Standards,
98291	Sealectro Corp., Mamaroneck, NY 10544
98474	Compar, Inc., Burlingame, CA 94010
98821	North Hills Electronic, Glen Cove, NY 11542
99117	Metavac, Inc., Flushing, NY 11358
99313	Varian Associates, Palo Alto, CA 94303
99378	Atlee Corp., Winchester, MA 01890
99800	Delevan Electronics, East Aurora, NY 14052

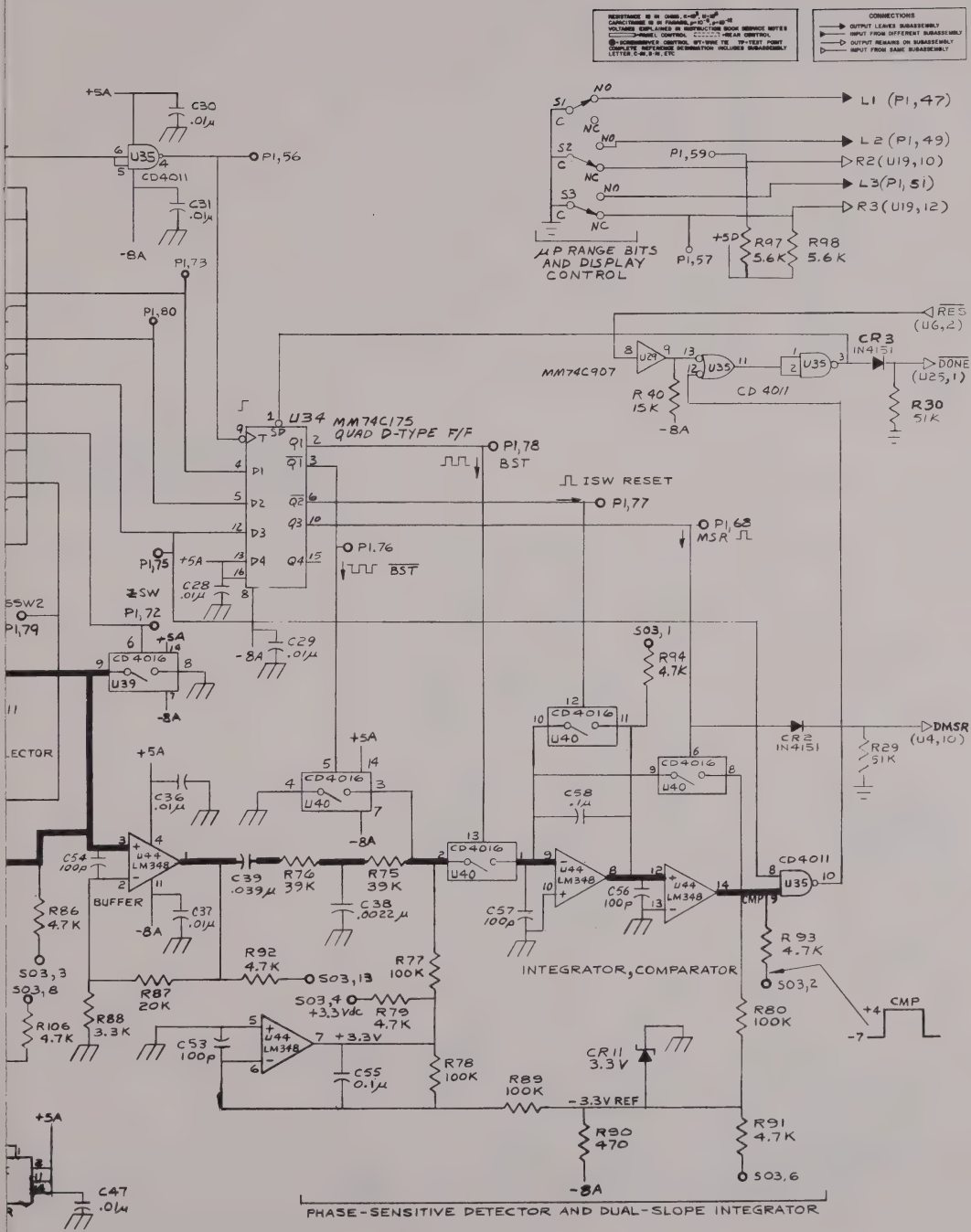

Figure 6-3. Analog and control (C) board, -4700, front end diagram.

FEDERAL MANUFACTURER'S CODE

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(Name to Code) and H4-2 (Code to Name) as supplemented through August, 1968.

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01295	Texas Instruments, Inc., Dallas, TX 75222
01930	Amerock, Corp., Rockford, IL 61101
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02606	Fenwal Lab Inc., Morton Grove, IL 60053
02660	Amphenol Electron Corp., Broadview, IL 60153
02768	Fastex, Des Plains, IL 60016
03042	Carter Ink Co., Cambridge, MA 02142
03508	G. E. Semicon Prod., Syracuse, NY 13201
03636	Grayburne, Yonkers, NY 10701
03877	Transitron Electronics, Wakefield, MA 01880
03911	Clairex Corp., New York, NY 10001
04009	Arrow Hart, Hartford, CT 06106
04643	Digitronics Corp., Albertson, NY 11507
04713	Motorola, Phoenix, AZ 85008
04919	Component Mfg. Service, Inc., West Bridgewater, MA 02379
05079	Tansitor Electronics, Bennington, VT 05201
05402	Controls Co. of America, Melrose Park, IL 60160
05574	Viking Industries, Inc., Chatsworth, CA 91311
05624	Barber-Colman Co., Rockford, IL 61101
05748	Barnes Mfg. Co., Mansfield, OH 44901
05820	Wakefield Engineering Inc., Wakefield, MA 01880
06743	Clevite Corp., Cleveland, OH 44110
07126	Digitran Co., Pasadena, CA 91106
07127	Eagle Signal (E.W. Bliss Co.), Baraboo, WI 53913
07233	Cinch Graphik, City of Industry, CA 91744
07261	Avnet Corp., Culver City, CA 90230
07263	Fairchild Semiconductor, Mountain View, CA 94040
07387	Birtcher Corp., No. Los Angeles, CA 90032
07595	Amer. Semiconductor, Arlington Hts, IL 60004
07828	Bodine Corp., Bridgeport, CT 06605
07829	Bodine Electric Co., Chicago, IL 60618
07910	Cont. Device Corp., Hawthorne, CA 90250
07983	State Labs, Inc., New York, NY 10003
07999	Borg Instruments, Delavan, WI 53115
08730	Vemaline Products Co., Franklin Lakes, NJ 07417
09213	G. E. Semiconductor, Buffalo, NY 14207
09353	C & K Components Inc., Watertown, MA 02172
09408	Star-Tronics Inc., Georgetown, MA 01830
09823	Burgess Battery Co., Freeport, IL 61032
09856	Fenwal Electronics, Inc., Framingham, MA 01701
09922	Burndy Corp., Norwalk, CT 06852
11236	CTS of Berne, Inc., Berne, IN 46711
11599	Chandler Evans Corp., W. Hartford, CT 06101
11983	Nortronics Co., Inc., Minneapolis, MN 55427
12040	National Semiconductor, Santa Clara, CA 95051
12045	Electronic Transistors Corp., Flushing, NY 11354
12498	Teledyne Semiconductor, Mountain View, CA 94043
12617	Hamlin, Inc., Lake Millis, WI 53551
12672	R. C. A., Woodridge, NJ 07095
12697	Clarostat Mfg. Co., Inc., Dover, NH 03820
12954	Dickson Electronics Corp., Scottsdale, AZ 85252
12969	Unitrode Corp., Watertown, MA 02172
13094	Electrocraft Corp., Hopkins, MN 55343
13103	Thermalloy, Inc., Dallas, TX 75234
13327	Solitron Devices, Inc., NY 10983
13919	Burr Brown Research Corp., Tucson, AZ 85706
14195	Electronic Controls, Inc., Wilton, CT 06897
14433	I.T.T. Semiconductors, W. Palm Beach, FL 33402
14482	Watkins & Johnson Co., Palo Alto, CA 94304
14655	Cornell Dubilier Electronics, Newark, NJ 07101
14674	Corning Glass Works, Corning, NY 14830
14749	Acoplan, Easton, PA 18042
14752	Electro Cube, Inc., San Gabriel, CA 91776
14936	General Instrument Corp., Hicksville, NY 11802
15116	Microdot Magnetics, Inc., Los Angeles, CA 90053
15238	I.T.T. Semiconductors, Lawrence, MA 08142
15476	Digital Equipment Corp., Maynard, MA 01754
15605	Cutler Hammer, Inc., Milwaukee, WI 53202
15782	Houston Instrument Corp., Bellaire, TX 77401
16037	Spruce Pine Mica Co., Spruce Pine, NC 28777
16179	Omni Spectra Mich Div., Farmington, MI 48024
16352	Computer Diode Corp., Lodi, NJ 07644
16636	Indiana General Corp., Oglesby, IL 61348
16758	Delco Electronic Div., GMC, Kokomo, IN 46901
16960	Precision Dynamics Corp., Burbank, CA 91504
16962	American Micro Devices, Inc., Summerville, SC 29483
17117	Electronic Molding Corp., Woonsocket, RI 02895
17771	Singer Co., Diehl Div., Somerville, NJ 08876
17850	Zeltex, Inc., Concord, CA 94520
17856	Siliconix, Inc., Santa Clara, CA 95054
18324	Signetics, Corp., Sunnyvale, CA 94086
18542	New Product Engineering Inc., Wabash, IN 46992
18677	Scanbe Manufacturing Corp., El Monte, CA 91731
18736	Voltronics Corp., Hanover, NJ 07936
18736	Computer Diode Corp., S. Fairlawn, NJ 07936
19048	Computer Diode Corp., S. Fairlawn, NJ 07410
19178	Zero Manufacturing Co., Monson, MA 01057
19373	Eastron Corp., Haverhill, MA 01830
19396	Illinois Tool Works, Pakton Div., Chicago, IL 60634
19617	Cabtron Corp., Chicago, IL 60622
19644	L.R.C. Electronics, Horseheads, NY 14845
19701	Electra Mfg. Co., Independence, KS 67301
20754	K.M.C. Semiconductor, Long Valley, NJ 07853
21335	Fafnir Bearing Co., New Britain, CT 06050
21759	Lenox-Fugle Electronics, Watchung, NJ 07060
22753	UID Electronics Div., AMF Inc., Hollywood, FL 33022
23338	Wavetek Div., John Fluke, San Diego, CA 92112
23342	Avnet Electronics Corp., Franklin Park, IL 60131
24355	Analog Devices, Cambridge, MA 02142
24446	General Electric, Schenectady, NY 12305
24454	General Electric Electronics Comp., Syracuse, NY 13201
24455	General Electric Lamp Div., Cleveland, OH 44112
24602	E.M.C. Technology, Cherry Hill, NJ 08034
24655	General Radio Co., Concord, MA 01742
25289	E. G. & G. Inc., Bedford, MA 01730
26806	American Zettler, Inc., Costa Mesa, CA 92626
28480	Hewlett Packard, Palo Alto, CA 04304
28520	Heyman Mfg. Co., Kenilworth, NJ 07033
28959	Hoffman Electronics Corp., El Monte, CA 91734
30646	Beckman Instruments, Inc., Cedar Grove, NJ 07009
30874	I.B.M., Armonk, NY 10504
32001	Jensen Mfg. Co., Chicago, IL 60638
33173	General Electric Comp., Owensboro, KY 42301
34141	Koehler Mfg. Co., Inc., Marlboro, MA 01752
35929	Constanta, Co., Montreal Quebec
37942	P. R. Mallory & Co., Inc., Indianapolis, IN 46206
38443	Marlin-Rockwell Corp., Jamestown, NY 14701
39317	McGill Manufacturing Co., Inc., Valparaiso, IN 46383
40931	Honeywell, Inc., Minneapolis, MN 55408
42190	Muter Co., Chicago, IL 60638
42498	National Co., Inc., Melrose, MA 02176
43991	Norma Hoffman, Stanford, CT 06904
49671	R. C.A., New York, NY 10020
49956	Raytheon Mfg. Co., Waltham, MA 02154
50088	Mostek, Carrollton, TX 75006
53021	Sangamo Electric Co., Springfield, IL 62705
54294	Shallcross Mfg. Co., Selma, NC 27576
54715	Shure Brothers, Inc., Evanston, IL 60202
56289	Sprague Electric Co., North Adams, MA 01247
59730	Thomas & Betts Co., Elizabeth, NJ 07207
59875	T.R.W. Inc., (Accessories Div), Cleveland, OH 44117
60395	Torrington Mfg. Co., Torrington, CT 06790
61637	Union Carbide Corp., New York, NY 10017
61864	United-Carr Fastener Corp., Boston, MA 02142
63060	Victoreen Instrument Co., Cleveland, OH 44104
63743	Ward Leonard Electric, Mt. Vernon, NY 10550
65083	Westinghouse (Lamp Div), Bloomfield, NJ 07003
65092	Weston Instruments, Newark, NJ 07114
70106	Acushnet Capacitor Co., New Bedford, MA 02742
70109	Adams and Westlake Co., Elkhart, IN 46514
70485	Atlantic India Rubber Works, Inc., Chicago, IL 60607
70563	Amperite Co., Union City, NJ 07087
70903	Belden Mfg. Co., Chicago, IL 60644
71126	Bronson Homer D., Beacon Falls, CT 06403
71279	Cambridge Thermionic, Corp., Cambridge, MA 02138
71294	Canfield Co., Clifton Forge, VA 24422
71400	CTS Corp., Elkhart, IN 46514
71450	CTS Corp., Elkhart, IN 46514
71468	ITT-Cannon Electric Inc., Los Angeles, CA 90031
71482	C.P. Clare & Co., Chicago, IL 60645
71590	Centralab, Inc., Milwaukee, WI 53212
71666	Continental Carbon Co., Inc., New York, NY 10001
71707	Coto Coil Co., Inc., Providence, RI 02905
71729	Crescent Box Corp., E. Philadelphia, PA 19134
71744	Chicago Miniature Lamp, Chicago, IL 60640
71785	Cinch Jones, Chicago, IL 60624
71823	Darnell Corp., Ltd., Downey, CA 90241
72136	Electromotive Mfg. Co., Willimantic, CT 06226
72228	Continental Screw Co., New Bedford, MA 02742
72259	Nytronics, Inc., Berkeley Hts, NJ 07922
72619	Dialight Co., Brooklyn, NY 11237
72699	General Instrument Corp., Newark, NJ 07104
72765	Drake Mfg. Co., Chicago, IL 60631
72794	Dzus Fastener Co., Inc., West Islip, NY 11795
72825	Eby Co., Hugh H, Philadelphia, PA 19144
72962	Elastic Stop Nut Corp., Union, NJ 07083
72982	Erie Technological Products, Erie, PA 16512
73445	Amperex Electronic Corp., Hicksville, LI, NY 11801
73559	Carling Electric Co., W. Hartford, CT 06110
73690	Elco Resistor Co., New York, NY 10001
73899	J.F.D. Electronics Corp., Brooklyn, NY 11219
73957	Groov-Pin Corp., Ridgefield, NJ 07657
74193	Heinemann Electric Co., Trenton, NJ 08602
74545	Hubbell, Stratford, CT 06497
74861	Industrial Condenser Corp., Chicago, IL 60618
74868	Amphenol RF Division, Danbury, CT 06810
74970	Johnson Co., E.F., Waseca, MN 56093
75042	IRC Div. of TRW, Burlington, IA 52601
75382	Kulka Electric Corp., Mt. Vernon, NY 10551
75491	Lafayette Industrial Electronics, Syosset, NY 11791
75608	Linden & Co., Providence, RI 02905
75915	Littelfuse, Inc., Des Plaines, IL 60016
76005	Lord Mfg. Co., Erie, PA 16512
76149	Mallory Electric Corp., Detroit, MI 48204
76381	Minnesota Mining., St. Paul, MN 55101
76487	Millen Mfg. Co., Inc., Malden, MA 02148
76545	Mueller Electric Co., Cleveland, OH 44114
76684	National Tube Co., Pittsburg, PA 15230
76854	Oak Mfg. Co., Crystal Lake, IL 60014
77147	Patton MacGuyer Co., Providence, RI 02905
77166	Pass-Seymour, Syracuse, NY 13209
77263	Pierce-Roberts Rubber Co., Trenton, NJ 08638
77339	Positive Insulator Co., Newark, NJ 07101
77342	American Machine & Foundry Co., Princeton, IN 47570
77542	Ray-O-Vac Co., Madison, WI 53703
77630	T.R.W. Electronic Comp., Camden, NJ 08103
77638	General Instruments Corp., Brooklyn, NY 11211
78189	Shakeproof (Ill. Tool Wks), Elgin, IL 60120
78277	Sigma Instruments Inc., South Braintree, MA 02184
78488	Stackpole Carbon Co., St. Mary's, PA 15827
78553	Tinnerman Products, Inc., Cleveland, OH 44101
79089	R.C.A. Rec. Tube & Semicond., Harrison, NJ 07029
79136	Waldes Kohinoor Co., New York, NY 11101
79725	Wiremold Co., Hartford, CT 06110
79727	Continental WIRT Electronics Corp., Philadelphia, PA 19101
79963	Zierick Mfg. Co., Mount Kisco, NY 10549
80009	Tektronix, Inc., Beaverton, OR 97005
80030	Prestole Fastener, Toledo, OH 43605
80045	Vickers Inc., St. Louis, MO 63166
80103	Lambda Electronics Corp., Melville, NY 11746
80183	Sprague Products Co., North Adams, MA 01247
80211	Motorola Inc., Franklin Park, IL 60131
80251	Formica Corp., Cincinnati, OH 45232
80258	Standard Oil Co., Lafayette, IN 47902
80294	Bourns Laboratories, Inc., Riverside, CA 92506
80368	Sylvania Electric Products, Inc., New York, NY 10017
80431	Air Filter Corp., Milwaukee, WI 53218
80583	Hammarlund Co., Inc., New York, NY 10010
80894	Pure Carbon Co., St. Mary's, PA 15857
81030	International Instrument, Orange, CT 06477
81073	Grayhill Inc., LaGrange, IL 60525
81143	Isolantite Mfg. Corp., Stirling, NJ 07980
81312	Winchester Electronics Co., Inc., Oakville, CT 06779
81349	Military Specifications
81350	Joint Army-Navy Specifications
81483	International Rectifier Corp., El Segundo, CA 90245
81751	Columbus Electronics Corp., Yonkers, NY 10701
81831	Filtron Co., Flushing, NY 11354
81860	Barry Wright Corp., Watertown, MA 02172
82219	Sylvania Elec. Prod., Emporium, PA 15834
82273	Indiana Pattern & Model Works, LaPort, IN 46350
82389	Switchcraft, Inc., Chicago, IL 60630
82647	Metals & Controls, Inc., Attleboro, MA 02703
82807	Milwaukee Resistor Co., Milwaukee, WI 53204
82877	Rotron Mfg. Co., Inc., Woodstock, NY 12498
83003	Varo Semiconductor Div., Garland, TX 75040
83033	Meissner Mfg., Mt. Carmel, IL 62863
83058	Carr Fastener Co., Cambridge, MA 02142
83186	Victory Engineering, Springfield, NJ 07081
83361	Bearing Specialty Co., San Francisco, CA 94101
83587	Solar Electric Corp., Warren, PA 16365
83594	Burroughs Corp., Plainfield, NJ 07061
83740	Union Carbide Corp., New York, NY 10017
84411	TRW Capacitor Division, Ogallala, NB 69153
84835	Lehigh Metal Products, Cambridge, MA 02140
84970	Sarkes Tarzian, Inc., Bloomington, IN 47401
84971	T.A. Mfg. Corp., Los Angeles, CA 90039
86577	Precision Metal Products, Stoneham, MA 02180
86684	R.C.A. (Elec. Comp. & Dev), Harrison, NJ 07029
86687	R.E. C. Corp., New Rochelle, NY 10801
86800	Cont. Electronics Corp., Brooklyn, NY 11222
88140	Cutler-Hammer Inc., Lincoln, IL 62656
88219	Gould Nat. Batteries, Inc., Trenton, NJ 08607
88419	Cornell Dubilier, Fuquay-Varina, NC 27526
88627	K & G Mfg. Co., New York, NY 10001
89462	Holtzer Cabot Corp., Boston, MA 02119
89665	United Transformer Co., Chicago, IL 60607
89870	Berkshire Transformer Corp., Kent, CT 06757
90201	Mallory Capacitor Co., Indianapolis, IN 46206
90303	Mallory Battery Co., Tarrytown, NY 10591
90634	Gulton Industries, Inc., Metuchen, NJ 08840
90750	Westinghouse Electric Corp., Boston, MA 02118
90952	Hardware Products Co., Reading, PA 19602
91032	Continental Wire Corp., York, PA 17405
91146	I.T.T. (Cannon), Salem, MA 01970
91210	Gerber Mfg. Co., Mishawaka, IN 46544
91293	Johanson Mfg. Co., Boonton, NJ 07005
91417	Harris Semiconductor, Melbourne, FL 32901
91506	Augat Brothers, Inc., Attleboro, MA 02703
91598	Chandler Co., Wethersfield, CT 06109
91637	Dale Electronics, Inc., Columbus, NE 68601
91662	Elco Corp., Willow Grove, PA 19090
91719	General Instruments Corp., Dallas, TX 75220
91836	Kings Electronics, Co., Inc., Tuckahoe, NY 11223
91916	Mephisto Tool Co., Inc., Hudson, NY 12534
91929	Honeywell, Inc., Freeport, IL 61032
92519	Electra Insul. Corp., Woodside, LI., NY 11377
92678	Edgerton Germeshuasen, Georgetown, MA 01830
92702	I.M.C. Magnetics Corp., Westbury, NY 11591
92739	Ampex Corp., Redwood City, CA 94063
92966	Hudson Lamp Co., Kearny, NJ 07032
93332	Sylvania Elec. Prods., Inc., Woburn, MA 01801
93618	R & C Mfg. Co. of Penn, Inc., Ramsey, PA 16671
93916	Cramer Products Co., New York, NY 10013
94144	Raytheon Co., Components Div., Quincy, MA 02169
94154	Tung Sol Electric Inc., Newark, NJ 07101
94271	Weston Instruments, Inc., Archibald, PA 18403
94322	Tel Labs, Manchester, NH 03103
94589	Dickson Co., Chicago, IL 60619
94696	Magnecraft Electric Co., Chicago, IL 60630
94800	Atlas Industrial Corp., Brookline, NH 03033
95076	Garde Mfg. Co., Cumberland, RI 02864
95121	Quality Components, Inc., St. Marys, PA 15857
95146	Alco Electronics Mfg. Co., Lawrence, MA 01843
95238	Continental Connector Corp., Woodside, NY 11377
95275	Vitramon, Inc., Bridgeport, CT 06601
95348	Gordos Corp., Bloomfield, NJ 07003
95354	Methode Mfg. Co., Rolling Meadow, IL 60008
95794	American Brass Co., Torrington, CT 06790
95987	Weckesser Co., Inc., Chicago, IL 60646
96095	Hi Q Division of Aerovox Corp., Olean, NY 14760
96341	Microwave Associates, Inc., Burlington, MA 01801
96906	Military Standards
98291	Sealectro Corp., Mamaroneck, NY 10544
98474	Compar, Inc., Burlingame, CA 94010
98821	North Hills Electronic, Glen Cove, NY 11542
99117	Metavac, Inc., Flushing, NY 11358
99313	Varian Associates, Palo Alto, CA 94303
99378	Atlee Corp., Winchester, MA 01890
99800	Delevan Electronics, East Aurora, NY 14052

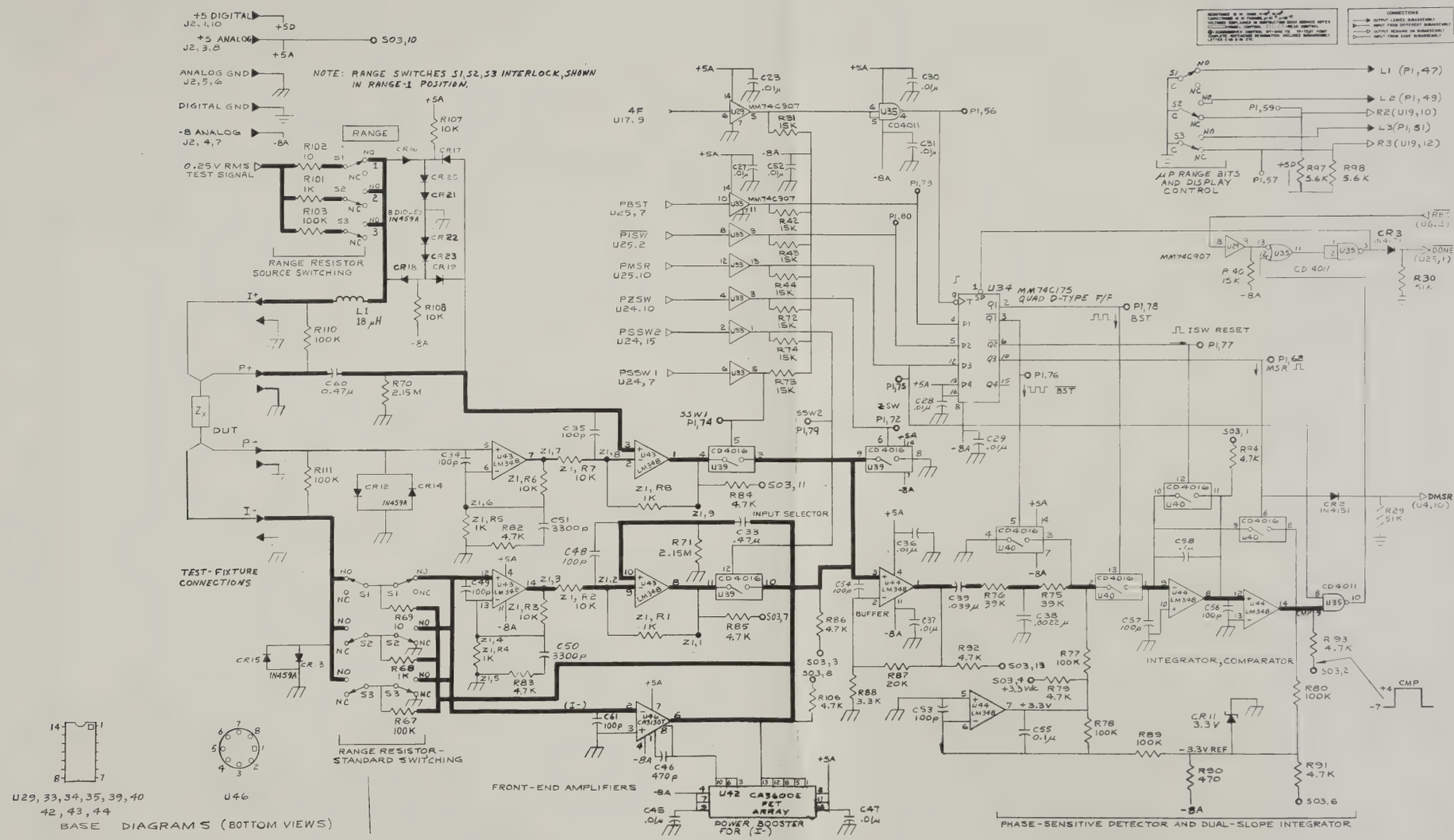
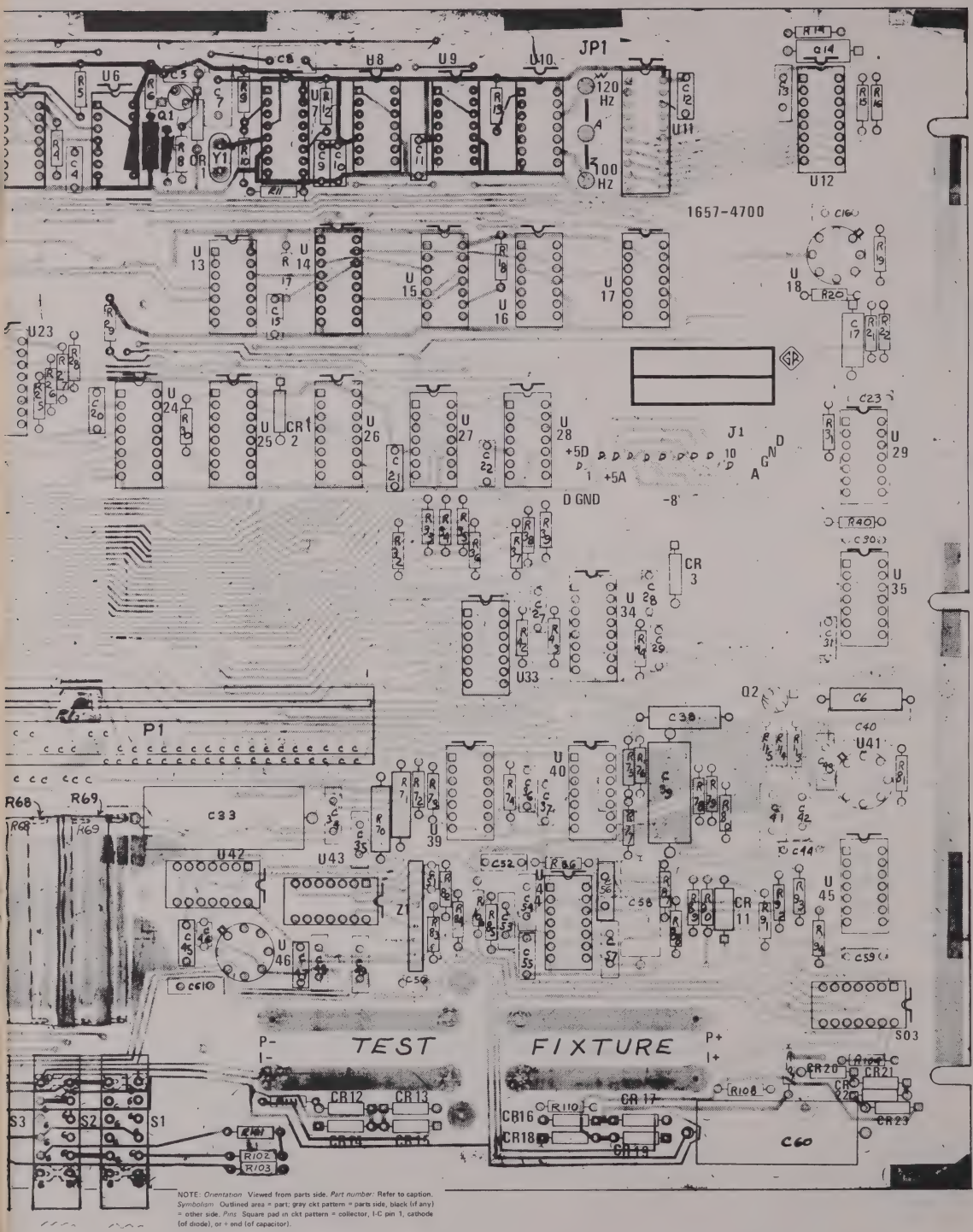


Figure 6-3. Analog and control (C) board, -4700, front end diagram.



6-4. Analog and control (C) board, 1657-4700, layout.

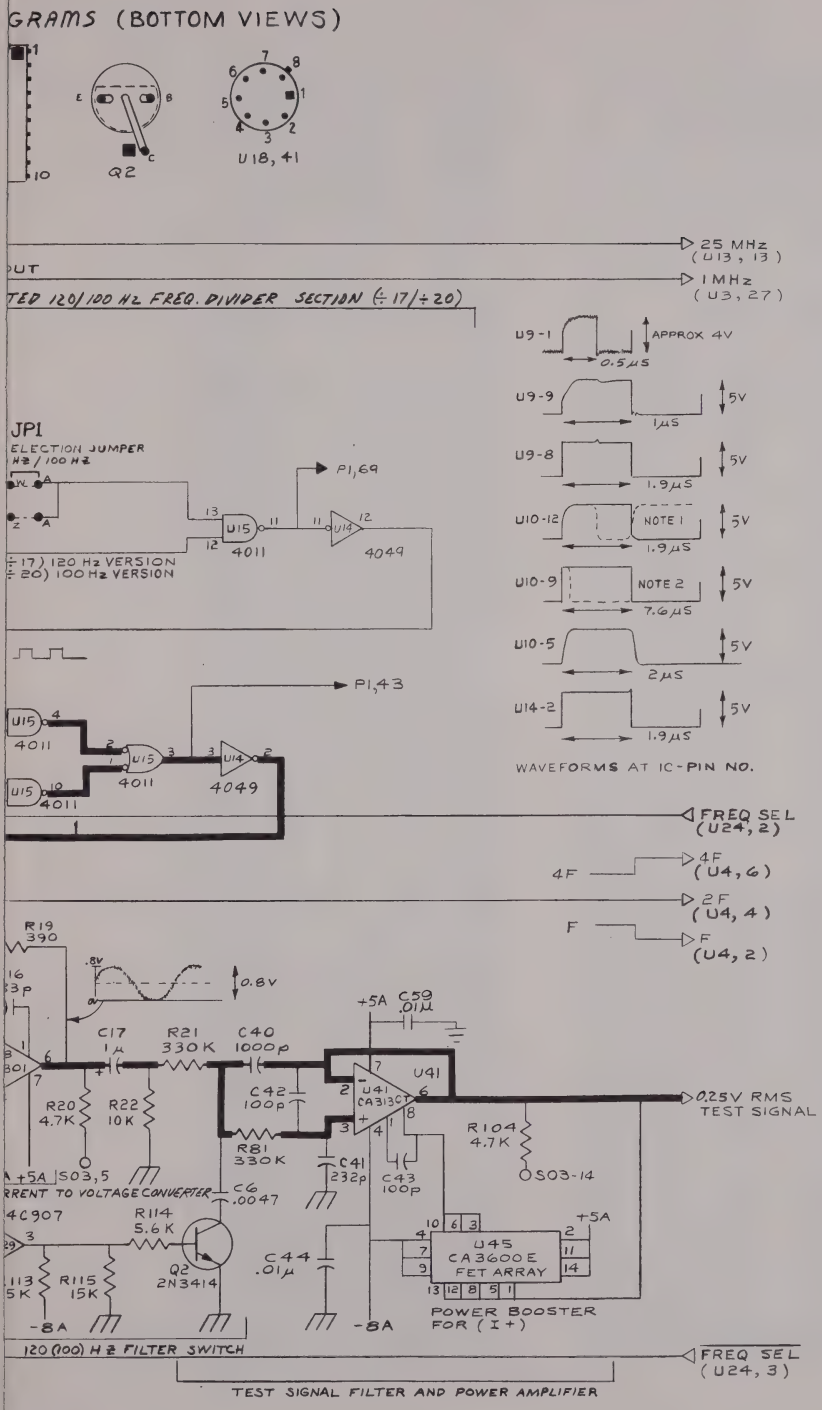


Figure 6-5. Analog and control (C) board, -4700, signal sources diagram.

NOTE: *Orientation:* Viewed from parts side. *Part number:* Refer to caption. *Symbolism:* Outlined area = part; gray ckt pattern = parts side, black (if any) = other side. *Pins:* Square pad in ckt pattern = collector, I-C pin 1, cathode (of diode), or + end (of capacitor).

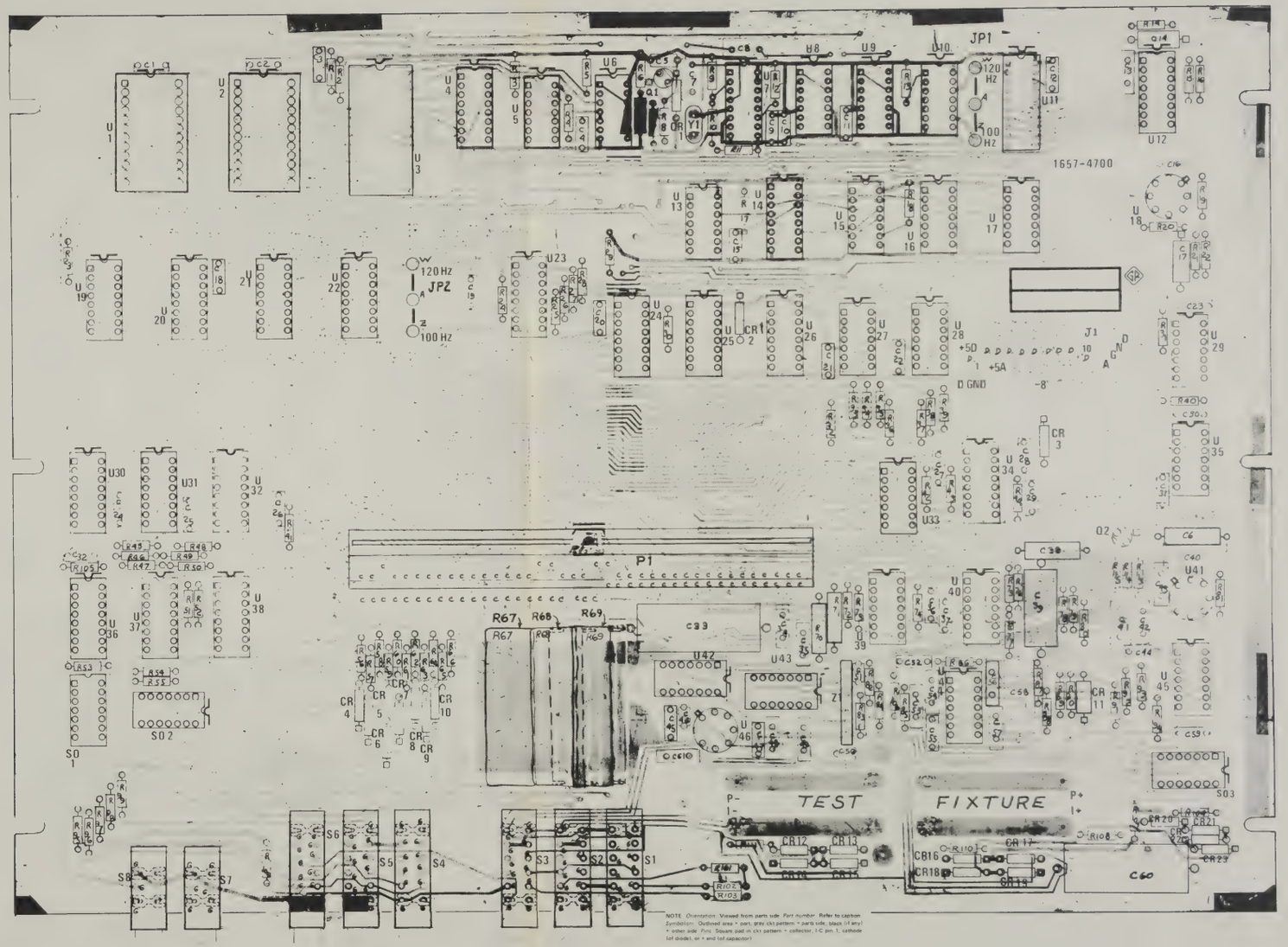

1657-4700
JP1
120 HZ
100 HZ
JP2
P1
J1
TEST
FIXTURE
+5D
+5A
DGND
-8
NOTE Orientation Viewed from parts side Part number Refer to caption Symbolism Outlined area = part, gray ckt pattern = parts side, black (if any) = other side Pins Square pad in ckt pattern = collector, I-C pin 1, cathode (of diode), or + end (of capacitor)

Figure 6-4. Analog and control (C) board, 1657-4700, layout.

ELECTRICAL PARTS LIST

ANALOG AND CONTROL PC BOARD P/N 1657-4700

REFDES		DESCRIPTION	PART NO.	FMC	MFGR PART NUMBER
C	1	CAP CER MONO 0.1UF 20PCT 50VGP	4400-2050	72982	8131-M050-651-104M
C	2	CAP CER MONO 0.1UF 20PCT 50VGP	4400-2050	72982	8131-M050-651-104M
C	3	CAP CER MONO 0.1UF 20PCT 50VGP	4400-2050	72982	8131-M050-651-104M
C	4	CAP CER MONO 0.1UF 20PCT 50VGP	4400-2050	72982	8131-M050-651-104M
C	5	CAP CER MONO 1UF 20PCT 50VGP	4400-2070	72982	8131-M050-651-105M
C	6	CAP MYLAR .0047 UF 5PCT 100V	4860-7398	24655	4860-7398
C	7	CAP MICA 16 PF 5PCT 500V	4700-0210	81349	CM05CD160JN
C	8	CAP MICA 30 PF 5PCT 500V	4700-0237	81349	CM05ED300JN
C	9	CAP CER MONO 0.1UF 20PCT 50VGP	4400-2050	72982	8131-M050-651-104M
C	10	CAP CER MONO 0.1UF 20PCT 50VGP	4400-2050	72982	8131-M050-651-104M
C	11	CAP CER MONO 0.1UF 20PCT 50VGP	4400-2050	72982	8131-M050-651-104M
C	12	CAP CER MONO 0.1UF 20PCT 50VGP	4400-2050	72982	8131-M050-651-104M
C	13	CAP CER DISC 15PF 5PCT 500V	4404-0155	72982	0831082Z5D00150J
C	14	CAP TANT 6.8 UF 20PCT 6V	4450-4800	56289	150D685X0006A2
C	15	CAP CER DISC .01UF 80/20PCT 100V	4401-3100	72982	0805540Z5U00103Z
C	16	CAP CER DISC 33PF 5PCT 500V	4404-0335	72982	0831082Z5D00330J
C	17	CAP TANT 1.0 UF 20PCT 35V	4450-4300	56289	150D105X0035A2
C	18	CAP CER MONO 0.1UF 20PCT 50VGP	4400-2050	72982	8131-M050-651-104M
C	19	CAP CER MONO 0.1UF 20PCT 50VGP	4400-2050	72982	8131-M050-651-104M
C	20	CAP CER MONO 0.1UF 20PCT 50VGP	4400-2050	72982	8131-M050-651-104M
C	21	CAP CER MONO 0.1UF 20PCT 50VGP	4400-2050	72982	8131-M050-651-104M
C	22	CAP CER MONO 0.1UF 20PCT 50VGP	4400-2050	72982	8131-M050-651-104M
C	23	CAP CER DISC .01UF 80/20PCT 100V	4401-3100	72982	0805540Z5U00103Z
C	24	CAP CER MONO 0.1UF 20PCT 50VGP	4400-2050	72982	8131-M050-651-104M
C	25	CAP CER MONO 0.1UF 20PCT 50VGP	4400-2050	72982	8131-M050-651-104M
C	26	CAP CER MONO 0.1UF 20PCT 50VGP	4400-2050	72982	8131-M050-651-104M
C	27	CAP CER DISC .01UF 80/20PCT 100V	4401-3100	72982	0805540Z5U00103Z
C	28	CAP CER DISC .01UF 80/20PCT 100V	4401-3100	72982	0805540Z5U00103Z
C	29	CAP CER DISC .01UF 80/20PCT 100V	4401-3100	72982	0805540Z5U00103Z
C	30	CAP CER DISC .01UF 80/20PCT 100V	4401-3100	72982	0805540Z5U00103Z
C	31	CAP CER DISC .01UF 80/20PCT 100V	4401-3100	72982	0805540Z5U00103Z
C	32	CAP CER MONO 0.1UF 20PCT 50VGP	4400-2050	72982	8131-M050-651-104M
C	33	CAP MYLAR .47UF 10 PCT 100V	4860-8248	56289	410P 0.47 UF 10PCT
C	34	CAP CER DISC 100PF 5PCT 500V	4404-1105	72982	0831082Z5D00101J
C	35	CAP CER DISC 100PF 5PCT 500V	4404-1105	72982	0831082Z5D00101J
C	36	CAP CER DISC .01UF 80/20PCT 100V	4401-3100	72982	0805540Z5U00103Z
C	37	CAP CER DISC .01UF 80/20PCT 100V	4401-3100	72982	0805540Z5U00103Z
C	38	CAP MYLAR .0022UF 10 PCT 200V	4860-7329	56289	410P .0022 UF 10PCT
C	39	CAP MYLAR .039UF 10PCT 200V	4860-8009	56289	410P .039 UF 10PCT
C	40	CAP MICA 1000PF 1PCT 500V	4710-0100	81349	CM06FD102FN
C	41	CAP MICA 232PF 1PCT 500V	4710-0411	81349	CM05FD232FN
C	42	CAP CER DISC 100PF 5PCT 500V	4404-1105	72982	0831082Z5D00101J
C	43	CAP CER DISC 100PF 5PCT 500V	4404-1105	72982	0831082Z5D00101J
C	44	CAP CER DISC .01UF 80/20PCT 100V	4401-3100	72982	0805540Z5U00103Z
C	45	CAP CER DISC .01UF 80/20PCT 100V	4401-3100	72982	0805540Z5U00103Z
C	46	CAP CER.15SQ 470 PF 5PCT 100V	4400-6496	72982	8111A100Y5F471J
C	47	CAP CER DISC .01UF 80/20PCT 100V	4401-3100	72982	0805540Z5U00103Z
C	48	CAP CER DISC 100PF 5PCT 500V	4404-1105	72982	0831082Z5D00101J
C	49	CAP CER DISC 100PF 5PCT 500V	4404-1105	72982	0831082Z5D00101J
C	50	CAP CER .15SQ .0033UF 20PCT 100V	4400-6531	72982	8111A100Y5F332J
C	51	CAP CER .15SQ .0033UF 20PCT 100V	4400-6531	72982	8111A100Y5F332J
C	52	CAP CER DISC .01UF 80/20PCT 100V	4401-3100	72982	0805540Z5U00103Z
C	53	CAP CER DISC 100PF 5PCT 500V	4404-1105	72982	0831082Z5D00101J
C	54	CAP CER DISC 100PF 5PCT 500V	4404-1105	72982	0831082Z5D00101J
C	55	CAP CER MONO 0.1UF 20PCT 50VGP	4400-2050	72982	8131-M050-651-104M
C	56	CAP CER DISC 100PF 5PCT 500V	4404-1105	72982	0831082Z5D00101J
C	57	CAP CER DISC 100PF 5PCT 500V	4404-1105	72982	0831082Z5D00101J
C	58	CAP POLYPROPYL 0.1UF 10PCT 200V	4863-3000	84411	X363UW 0.1UF 10PCT
C	59	CAP CER DISC .01UF 80/20PCT 100V	4401-3100	72982	0805540Z5U00103Z
C	60	CAP MYLAR .47UF 10 PCT 100V	4860-8248	56289	410P 0.47 UF 10PCT
C	61	CAP CER DISC 100PF 5PCT 500V	4404-1105	72982	0831082Z5D00101J
CR	1	DIODE 1N455 30PIV IR 30UA GE	6082-1010	14433	1N455
CR	2	DIODE 1N4151 75PIV IR.1UA SI	6082-1001	14433	1N3604
CR	3	DIODE 1N4151 75PIV IR.1UA SI	6082-1001	14433	1N3604
CR	4	DIODE 1N4151 75PIV IR.1UA SI	6082-1001	14433	1N3604
CR	5	DIODE 1N4151 75PIV IR.1UA SI	6082-1001	14433	1N3604
CR	6	DIODE 1N4151 75PIV IR.1UA SI	6082-1001	14433	1N3604
CR	7	DIODE 1N4151 75PIV IR.1UA SI	6082-1001	14433	1N3604
CR	8	DIODE 1N4151 75PIV IR.1UA SI	6082-1001	14433	1N3604
CR	9	DIODE 1N4151 75PIV IR.1UA SI	6082-1001	14433	1N3604
CR	10	DIODE 1N4151 75PIV IR.1UA SI	6082-1001	14433	1N3604
CR	11	ZENER 1N746 3.3V 10PCT .4W	6083-1005	14433	1N746

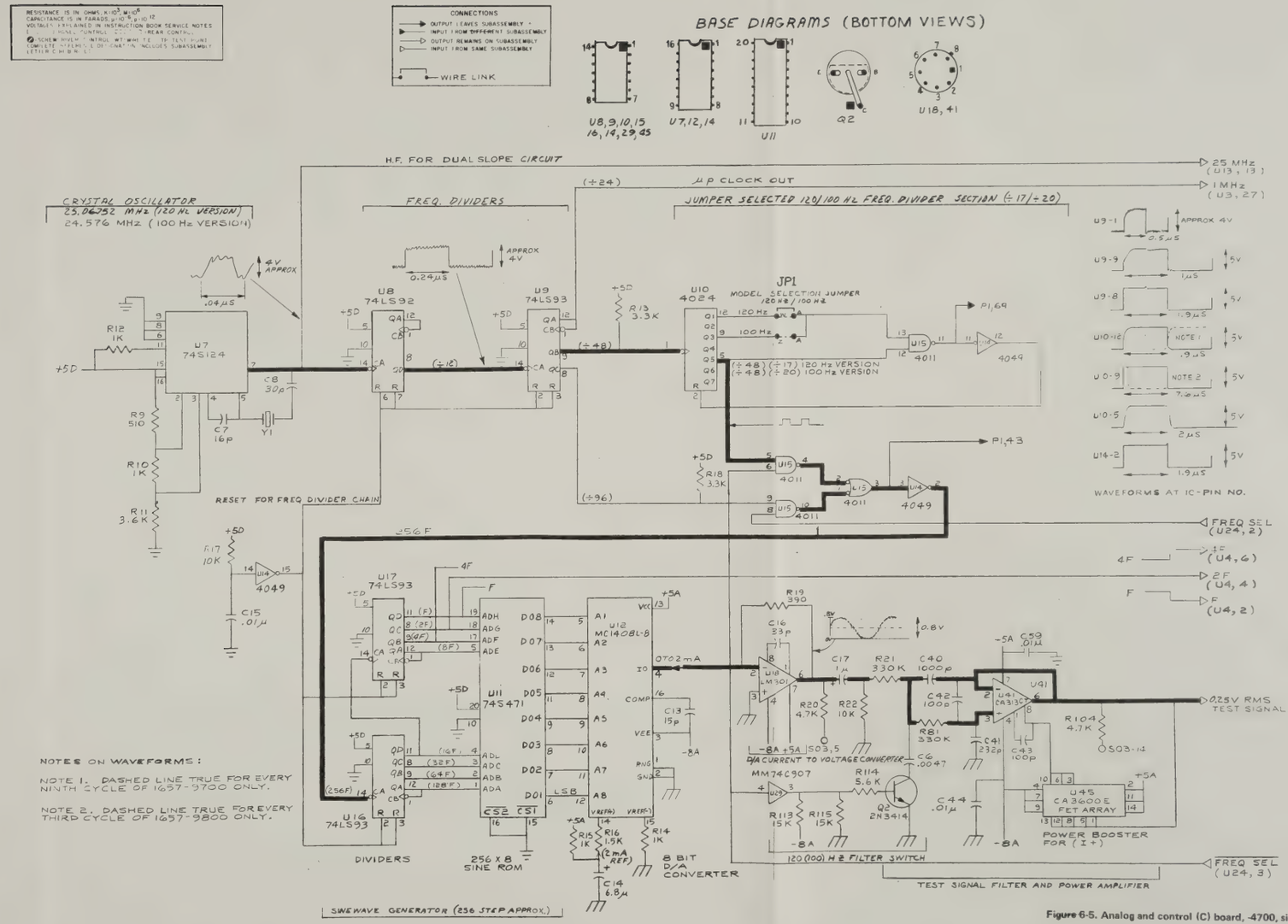

RESISTANCE IS IN OHMS, K=10³, M=10⁶
CAPACITANCE IS IN FARADS, μ=10⁻⁶, μμ=10⁻¹²
VOLTAGES OBTAINED IN INSTRUCTION BOOK SERVICE NOTES
CONNECTIONS
OUTPUT LEAVES SUBASSEMBLY
INPUT FROM DIFFERENT SUBASSEMBLY
OUTPUT REMAINS ON SUBASSEMBLY
INPUT FROM SAME SUBASSEMBLY
WIRE LINK
BASE DIAGRAMS (BOTTOM VIEWS)
U8,9,10,15 16,14,29,45
U7,12,14
U11
Q2
U18, 41
H.F. FOR DUAL SLOPE CIRCUIT
CRYSTAL OSCILLATOR
25.06252 MHz (120 Hz VERSION)
24.576 MHz (100 Hz VERSION)
FREQ. DIVIDERS
(÷24)
μP CLOCK OUT
JUMPER SELECTED 120/100 Hz FREQ. DIVIDER SECTION (÷17/÷20)
25 MHz (U13, 13)
1 MHz (U3, 27)
WAVEFORMS AT IC-PIN NO.
RESET FOR FREQ DIVIDER CHAIN
÷56 F
FREQ SEL (U24, 2)
4F (U4, 6)
2F (U4, 4)
F (U4, 2)
NOTES ON WAVEFORMS:
NOTE 1. DASHED LINE TRUE FOR EVERY NINTH CYCLE OF 1657-9700 ONLY.
NOTE 2. DASHED LINE TRUE FOR EVERY THIRD CYCLE OF 1657-9800 ONLY.
DIVIDERS
256 X 8 SINE ROM
8 BIT D/A CONVERTER
SINEWAVE GENERATOR (256 STEP APPROX.)
0.25V RMS TEST SIGNAL
D/A CURRENT TO VOLTAGE CONVERTER
120 (100) Hz FILTER SWITCH
POWER BOOSTER FOR (I+)
TEST SIGNAL FILTER AND POWER AMPLIFIER

Figure 6-5. Analog and control (C) board, -4700, signal sources diagram.

ANALOG AND CONTROL PC BOARD P/N 1657-4700

REFDES		DESCRIPTION	PART NO.	FMC	MFGR PART NUMBER
U	15	ICD 34011TC 14D Q 2IN NAND DIG	5431-7000	07263	34011TC
U	16	ICD SN74LS93N 4BIT BIN COUNTER	5431-8693	01295	SN74LS93N
U	17	ICD SN74LS93N 4BIT BIN COUNTER	5431-8693	01295	SN74LS93N
U	18	IC LINEAR LM301A	5432-1004	12040	LM301AH
U	19	IC DIGITAL MM80C97	5431-7043	12040	MM80C97
U	20	IC DIGITAL MM80C97	5431-7043	12040	MM80C97
U	21	IC DIGITAL MM80C97	5431-7043	12040	MM80C97
U	22	IC DIGITAL MM80C97	5431-7043	12040	MM80C97
U	23	IC DIGITAL SN74LS155N	5431-8755	01295	SN74LS155N
U	24	IC DIGITAL MM74C175	5431-7041	12040	MM74C175
U	25	IC DIGITAL MM74C175	5431-7041	12040	MM74C175
U	26	ICD CD4040AE 16D 12STGE BIN CNTR	5431-7018	86684	CD4040AE
U	27	ICD SN74LS93N 4BIT BIN COUNTER	5431-8693	01295	SN74LS93N
U	28	ICD SN74LS93N 4BIT BIN COUNTER	5431-8693	01295	SN74LS93N
U	29	IC DIGITAL MM74C907	5431-7042	12040	MM74C907
U	30	IC DIGITAL SN74LS174N	5431-8774	01295	SN74LS174N
U	31	IC DIGITAL SN74LS174N	5431-8774	01295	SN74LS174N
U	32	ICD SN74174N 16D HX D FLIFLO CLS	5431-8074	01295	SN74174N
U	33	IC DIGITAL MM74C907	5431-7042	12040	MM74C907
U	34	IC DIGITAL MM74C175	5431-7041	12040	MM74C175
U	35	ICD 34011TC 14D Q 2IN NAND DIG	5431-7000	07263	34011TC
U	36	IC DIGITAL SN74LS155N	5431-8755	01295	SN74LS155N
U	37	IC DIGITAL SN74LS155N	5431-8755	01295	SN74LS155N
U	38	ICD SN74174N 16D HX D FLIFLO CLS	5431-8074	01295	SN74174N
U	39	ICD CD4016AE 14D Q BIL SW	5431-7003	86684	CD4016AE
U	40	ICD CD4016AE 14D Q BIL SW	5431-7003	86684	CD4016AE
U	41	ICL CA3130T COS MOS	5432-7000	86684	CA3130T
U	42	IC FET ARRAY	5434-0122	86684	CA3600E
U	43	IC LINEAR LM348N	5432-1055	12040	LM348N
U	44	IC LINEAR LM348N	5432-1055	12040	LM348N
U	45	IC FET ARRAY	5434-0122	86684	CA3600E
U	46	ICL CA3130T COS MOS	5432-7000	86684	CA3130T
Y	1	CRYSTAL PIEZO 24.576MHZ	5075-1201	24655	5075-1201
		NOTE: The part listed above is used only in the 120-Hz version (1657-9700).			
Y	1	CRYSTAL PIEZO 25.06752MHZ	5075-1200	24655	5075-1200
		NOTE: The part listed above is used only in the 100-Hz version (1657-9800).			
Z	1	RESISTOR NETWORK	1657-0800	24655	1657-0800

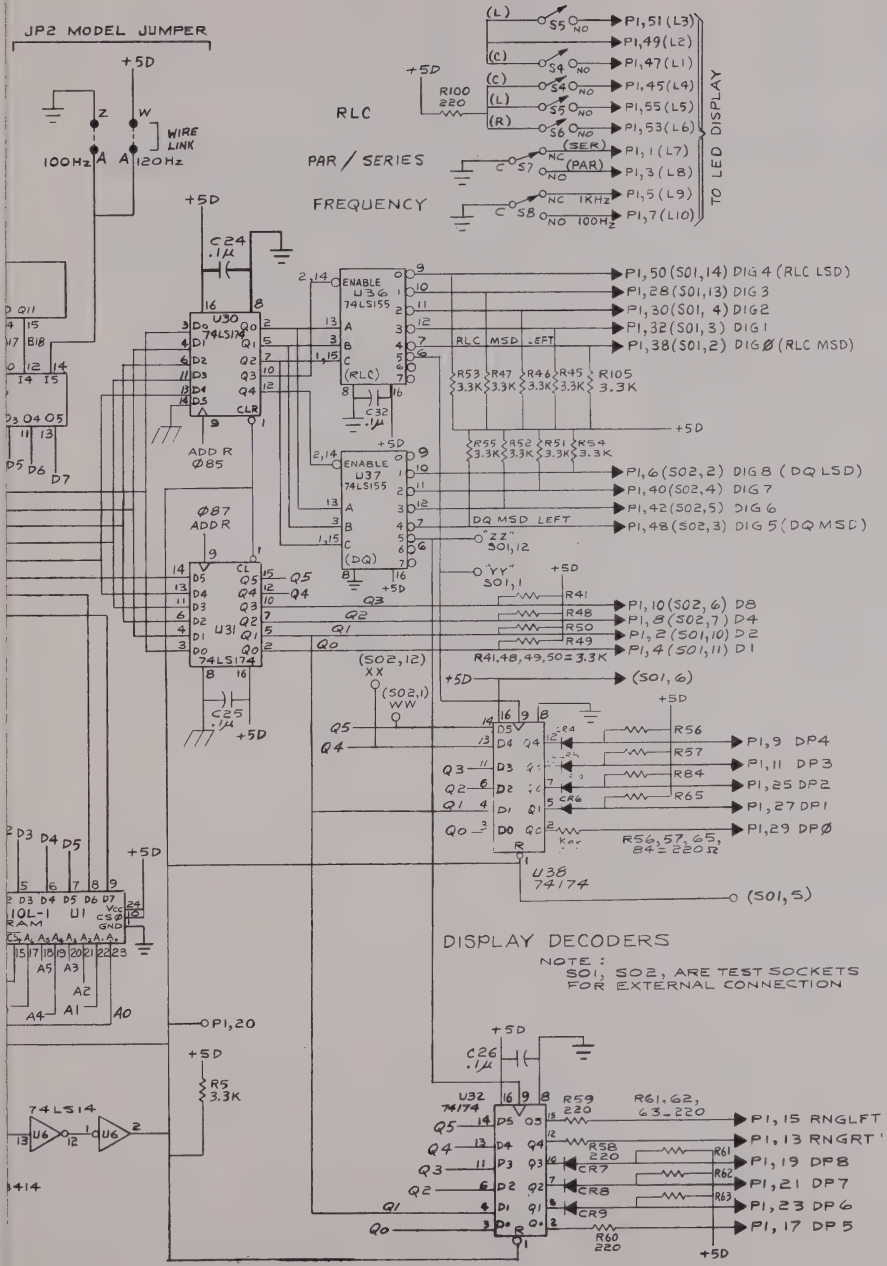


Figure 6-6. Analog and control (C) board, -4700, digital control diagram.

ELECTRICAL PARTS LIST (cont)

ANALOG AND CONTROL PC BOARD P/N 1657-4700

REFDES		DESCRIPTION	PART NO.	FMC	MFGR PART NUMBER
CR	12	DIODE RECTIFIER 175 PIV	6082-1011	14433	1N459A
CR	13	DIODE RECTIFIER 175 PIV	6082-1011	14433	1N459A
CR	14	DIODE RECTIFIER 175 PIV	6082-1011	14433	1N459A
CR	15	DIODE RECTIFIER 175 PIV	6082-1011	14433	1N459A
CR	16	DIODE RECTIFIER 175 PIV	6082-1011	14433	1N459A
CR	17	DIODE RECTIFIER 175 PIV	6082-1011	14433	1N459A
CR	18	DIODE RECTIFIER 175 PIV	6082-1011	14433	1N459A
CR	19	DIODE RECTIFIER 175 PIV	6082-1011	14433	1N459A
CR20...23		DIODE RECTIFIER 175 PIV	6082-1011	14433	1N459A
L	1	CHOKE, MOLDED 18 µH 10 PCT	4300-2500	99800	1537-42 18.0 µH
Q	1	TRANSISTOR 2N3414	8210-1047	03508	2N3414
Q	2	TRANSISTOR 2N3414	8210-1047	03508	2N3414
R	1	RES COMP 3.3 K 5PCT 1/4W	6099-2335	81349	RCR07G332J
R	2	RES COMP 3.3 K 5PCT 1/4W	6099-2335	81349	RCR07G332J
R	3	RES COMP 3.3 K 5PCT 1/4W	6099-2335	81349	RCR07G332J
R	4	RES COMP 3.3 K 5PCT 1/4W	6099-2335	81349	RCR07G332J
R	5	RES COMP 3.3 K 5PCT 1/4W	6099-2335	81349	RCR07G332J
R	6	RES COMP 10 K 5PCT 1/4W	6099-3105	81349	RCR07G103J
R	7	RES COMP 10 K 5PCT 1/4W	6099-3105	81349	RCR07G103J
R	8	RES COMP 1.0 K 5PCT 1/4W	6099-2105	81349	RCR07G102J
R	9	RES COMP 510 OHM 5PCT 1/4W	6099-1515	81349	RCR07G511J
R	10	RES COMP 1.0 K 5PCT 1/4W	6099-2105	81349	RCR07G102J
R	11	RES COMP 3.6 K OHM 5PCT 1/4W	6099-2365	81349	RCR07G362J
R	12	RES COMP 1.0 K 5PCT 1/4W	6099-2105	81349	RCR07G102J
R	13	RES COMP 3.3 K 5PCT 1/4W	6099-2335	81349	RCR07G332J
R	14	RES COMP 1.0 K 5PCT 1/4W	6099-2105	81349	RCR07G102J
R	15	RES COMP 1.0 K 5PCT 1/4W	6099-2105	81349	RCR07G102J
R	16	RES COMP 1.5 K 5PCT 1/4W	6099-2155	81349	RCR07G152J
R	17	RES COMP 10 K 5PCT 1/4W	6099-3105	81349	RCR07G103J
R	18	RES COMP 3.3 K 5PCT 1/4W	6099-2335	81349	RCR07G332J
R	19	RES COMP 390 OHM 5PCT 1/4W	6099-1395	81349	RCR07G391J
R	20	RES COMP 4.7 K 5PCT 1/4W	6099-2475	81349	RCR07G472J
R	21	RES COMP 330 K 5PCT 1/4W	6099-4335	81349	RCR07G334J
R	22	RES COMP 10 K 5PCT 1/4W	6099-3105	81349	RCR07G103J
R	23	RES COMP 5.6 K 5PCT 1/4W	6099-2565	81349	RCR07G562J
R	24	RES COMP 3.3 K 5PCT 1/4W	6099-2335	81349	RCR07G332J
R	25	RES COMP 3.3 K 5PCT 1/4W	6099-2335	81349	RCR07G332J
R	26	RES COMP 3.3 K 5PCT 1/4W	6099-2335	81349	RCR07G332J
R	27	RES COMP 3.3 K 5PCT 1/4W	6099-2335	81349	RCR07G332J
R	28	RES COMP 3.3 K 5PCT 1/4W	6099-2335	81349	RCR07G332J
R	29	RES COMP 51 K OHM 5PCT 1/4W	6099-3515	81349	RCR07G513J
R	30	RES COMP 51 K OHM 5PCT 1/4W	6099-3515	81349	RCR07G513J
R	31	RES COMP 15 K 5PCT 1/4W	6099-3155	81349	RCR07G153J
R	32	RES COMP 3.3 K 5PCT 1/4W	6099-2335	81349	RCR07G332J
R	33	RES COMP 3.3 K 5PCT 1/4W	6099-2335	81349	RCR07G332J
R	34	RES COMP 3.3 K 5PCT 1/4W	6099-2335	81349	RCR07G332J
R	35	RES COMP 3.3 K 5PCT 1/4W	6099-2335	81349	RCR07G332J
R	36	RES COMP 3.3 K 5PCT 1/4W	6099-2335	81349	RCR07G332J
R	37	RES COMP 3.3 K 5PCT 1/4W	6099-2335	81349	RCR07G332J
R	38	RES COMP 3.3 K 5PCT 1/4W	6099-2335	81349	RCR07G332J
R	39	RES COMP 3.3 K 5PCT 1/4W	6099-2335	81349	RCR07G332J
R	40	RES COMP 15 K 5PCT 1/4W	6099-3155	81349	RCR07G153J
R	41	RES COMP 3.3 K 5PCT 1/4W	6099-2335	81349	RCR07G332J
R	42	RES COMP 15 K 5PCT 1/4W	6099-3155	81349	RCR07G153J
R	43	RES COMP 15 K 5PCT 1/4W	6099-3155	81349	RCR07G153J
R	44	RES COMP 15 K 5PCT 1/4W	6099-3155	81349	RCR07G153J
R	45	RES COMP 3.3 K 5PCT 1/4W	6099-2335	81349	RCR07G332J
R	46	RES COMP 3.3 K 5PCT 1/4W	6099-2335	81349	RCR07G332J
R	47	RES COMP 3.3 K 5PCT 1/4W	6099-2335	81349	RCR07G332J
R	48	RES COMP 3.3 K 5PCT 1/4W	6099-2335	81349	RCR07G332J
R	49	RES COMP 3.3 K 5PCT 1/4W	6099-2335	81349	RCR07G332J
R	50	RES COMP 3.3 K 5PCT 1/4W	6099-2335	81349	RCR07G332J
R	51	RES COMP 3.3 K 5PCT 1/4W	6099-2335	81349	RCR07G332J
R	52	RES COMP 3.3 K 5PCT 1/4W	6099-2335	81349	RCR07G332J
R	53	RES COMP 3.3 K 5PCT 1/4W	6099-2335	81349	RCR07G332J
R	54	RES COMP 3.3 K 5PCT 1/4W	6099-2335	81349	RCR07G332J
R	55	RES COMP 3.3 K 5PCT 1/4W	6099-2335	81349	RCR07G332J
R	56	RES COMP 220 OHM 5PCT 1/4W	6099-1225	81349	RCR07G221J
R	57	RES COMP 220 OHM 5PCT 1/4W	6099-1225	81349	RCR07G221J

ELECTRICAL PARTS LIST (cont)

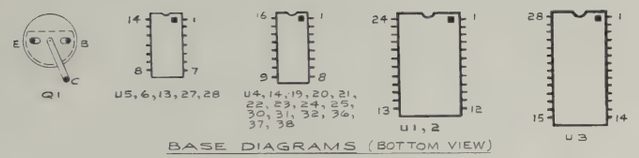
ANALOG AND CONTROL PC BOARD P/N 1657-4700

REFDES		DESCRIPTION	PART NO.	FMC	MFGR PART NUMBER
R	58	RES COMP 220 OHM 5PCT 1/4W	6099-1225	81349	RCR07G221J
R	59	RES COMP 220 OHM 5PCT 1/4W	6099-1225	81349	RCR07G221J
R	60	RES COMP 220 OHM 5PCT 1/4W	6099-1225	81349	RCR07G221J
R	61	RES COMP 220 OHM 5PCT 1/4W	6099-1225	81349	RCR07G221J
R	62	RES COMP 220 OHM 5PCT 1/4W	6099-1225	81349	RCR07G221J
R	63	RES COMP 220 OHM 5PCT 1/4W	6099-1225	81349	RCR07G221J
R	64	RES COMP 220 OHM 5PCT 1/4W	6099-1225	81349	RCR07G221J
R	65	RES COMP 220 OHM 5PCT 1/4W	6099-1225	81349	RCR07G221J
R	66	RES COMP 220 OHM 5PCT 1/4W	6099-1225	81349	RCR07G221J
R	67	RES GR 100K OHM .020 PCT 1W	6983-6000	24655	6983-6000
R	68	RES GR 1K OHM .02 PCT 1W	6983-4000	24655	6983-4000
R	69	RES GR 10.000 OHM .02PCT 1W	6983-2005	24655	6983-2005
R	70	RES FLM 2.15M 1 PCT 1/4W	6350-4215	81349	RN60D2154F
R	71	RES FLM 2.15M 1 PCT 1/4W	6350-4215	81349	RN60D2154F
R	72	RES COMP 15 K 5PCT 1/4W	6099-3155	81349	RCR07G153J
R	73	RES COMP 15 K 5PCT 1/4W	6099-3155	81349	RCR07G153J
R	74	RES COMP 15 K 5PCT 1/4W	6099-3155	81349	RCR07G153J
R	75	RES COMP 39 K 5PCT 1/4W	6099-3395	81349	RCR07G393J
R	76	RES COMP 39 K 5PCT 1/4W	6099-3395	81349	RCR07G393J
R	77	RES COMP 100 K 5PCT 1/4W	6099-4105	81349	RCR07G104J
R	78	RES COMP 100 K 5PCT 1/4W	6099-4105	81349	RCR07G104J
R	79	RES COMP 4.7 K 5PCT 1/4W	6099-2475	81349	RCR07G472J
R	80	RES COMP 100 K 5PCT 1/4W	6099-4105	81349	RCR07G104J
R	81	RES COMP 330 K 5PCT 1/4W	6099-4335	81349	RCR07G334J
R	82	RES COMP 4.7 K 5PCT 1/4W	6099-2475	81349	RCR07G472J
R	83	RES COMP 4.7 K 5PCT 1/4W	6099-2475	81349	RCR07G472J
R	84	RES COMP 4.7 K 5PCT 1/4W	6099-2475	81349	RCR07G472J
R	85	RES COMP 4.7 K 5PCT 1/4W	6099-2475	81349	RCR07G472J
R	86	RES COMP 4.7 K 5PCT 1/4W	6099-2475	81349	RCR07G472J
R	87	RES COMP 20 K OHM 5PCT 1/4W	6099-3205	81349	RCR07G203J
R	88	RES COMP 3.3 K 5PCT 1/4W	6099-2335	81349	RCR07G332J
R	89	RES COMP 100 K 5PCT 1/4W	6099-4105	81349	RCR07G104J
R	90	RES COMP 470 OHM 5PCT 1/4W	6099-1475	81349	RCR07G471J
R	91	RES COMP 4.7 K 5PCT 1/4W	6099-2475	81349	RCR07G472J
R	92	RES COMP 4.7 K 5PCT 1/4W	6099-2475	81349	RCR07G472J
R	93	RES COMP 4.7 K 5PCT 1/4W	6099-2475	81349	RCR07G472J
R	94	RES COMP 4.7 K 5PCT 1/4W	6099-2475	81349	RCR07G472J
R	95	RES COMP 5.6 K 5PCT 1/4W	6099-2565	81349	RCR07G562J
R	96	RES COMP 5.6 K 5PCT 1/4W	6099-2565	81349	RCR07G562J
R	97	RES COMP 5.6 K 5PCT 1/4W	6099-2565	81349	RCR07G562J
R	98	RES COMP 5.6 K 5PCT 1/4W	6099-2565	81349	RCR07G562J
R	99	RES COMP 5.6 K 5PCT 1/4W	6099-2565	81349	RCR07G562J
R	100	RES COMP 220 OHM 5PCT 1/4W	6099-1225	81349	RCR07G221J
R	101	RES COMP 1.0 K 5PCT 1/4W	6099-2105	81349	RCR07G102J
R	102	RES COMP 10 OHM 5PCT 1/4W	6099-0105	81349	RCR07G100J
R	103	RES COMP 100 K 5PCT 1/4W	6099-4105	81349	RCR07G104J
R	104	RES COMP 4.7 K 5PCT 1/4W	6099-2475	81349	RCR07G472J
R	105	RES COMP 3.3 K 5PCT 1/4W	6099-2335	81349	RCR07G332J
R	106	RES COMP 4.7 K 5PCT 1/4W	6099-2475	81349	RCR07G472J
R	107	RES COMP 10 K 5PCT 1/4W	6099-3105	81349	RCR07G103J
R	108	RES COMP 10 K 5PCT 1/4W	6099-3105	81349	RCR07G103J
R	110	RES COMP 100 K 5PCT 1/4W	6099-4105	81349	RCR07G104J
R	111	RES COMP 100 K 5PCT 1/4W	6099-4105	81349	RCR07G104J
R	113	RES COMP 15 K 5PCT 1/4W	6099-3155	81349	RCR07G153J
R	114	RES COMP 5.6 K 5PCT 1/4W	6099-2565	81349	RCR07G562J
R	115	RES COMP 15 K 5PCT 1/4W	6099-3155	81349	RCR07G153J
S	1	SWITCH PUSHBUTTON MULT 10 SECT	7880-2540	24655	7880-2540
U	1	IC RAM	5431-2425	04713	MCM6810AL
U	2	IC ROM	1657-0450	24655	1657-0450
U	3	IC MICROPROCESSOR	5431-2403	24655	5431-2403
U	4	IC DIGITAL MM80C97	5431-7043	12040	MM80C97
U	5	IC DIGITAL SN74LS32N	5431-8632	01295	SN74LS32N
U	6	IC DIGITAL SN74LS04N	5431-8604	01295	SN74LS04N
U	7	IC DIGITAL SN74S124	5431-8524	01295	SN74S124
U	8	IC DIGITAL SN74LS92	5431-8692	01295	SN74LS92
U	9	ICD SN74LS93N 4BIT BIN COUNTER	5431-8693	01295	SN74LS93N
U	10	ICD CD4024AE 14D 7ST BIN CNT	5431-7008	86684	CD4024AE
U	11	INTEGRATED CIRCUIT PROM	1657-0460	24655	1657-0460
U	12	D/A CONV 8 BIT MONOLITHIC	5429-5043	50721	DACIC8BC
U	13	IC DIGITAL SN74LS00N	5431-8600	01295	SN74LS00N
U	14	ICD CD4049AE 16D HEX INVERTER	5431-7021	86684	CD4049AE

ELECTRICAL PARTS LIST (cont)

ANALOG AND CONTROL PC BOARD P/N 1657-4700

REFDES		DESCRIPTION	PART NO.	FMC	MFGR PART NUMBER
U	15	ICD 34011TC 14D Q 2IN NAND DIG	5431-7000	07263	34011TC
U	16	ICD SN74LS93N 4BIT BIN COUNTER	5431-8693	01295	SN74LS93N
U	17	ICD SN74LS93N 4BIT BIN COUNTER	5431-8693	01295	SN74LS93N
U	18	IC LINEAR LM301A	5432-1004	12040	LM301AH
U	19	IC DIGITAL MM80C97	5431-7043	12040	MM80C97
U	20	IC DIGITAL MM80C97	5431-7043	12040	MM80C97
U	21	IC DIGITAL MM80C97	5431-7043	12040	MM80C97
U	22	IC DIGITAL MM80C97	5431-7043	12040	MM80C97
U	23	IC DIGITAL SN74LS155N	5431-8755	01295	SN74LS155N
U	24	IC DIGITAL MM74C175	5431-7041	12040	MM74C175
U	25	IC DIGITAL MM74C175	5431-7041	12040	MM74C175
U	26	ICD CD4040AE 16D 12STGE BIN CNTR	5431-7018	86684	CD4040AE
U	27	ICD SN74LS93N 4BIT BIN COUNTER	5431-8693	01295	SN74LS93N
U	28	ICD SN74LS93N 4BIT BIN COUNTER	5431-8693	01295	SN74LS93N
U	29	IC DIGITAL MM74C907	5431-7042	12040	MM74C907
U	30	IC DIGITAL SN74LS174N	5431-8774	01295	SN74LS174N
U	31	IC DIGITAL SN74LS174N	5431-8774	01295	SN74LS174N
U	32	ICD SN74174N 16D HX D FLIFLO CLS	5431-8074	01295	SN74174N
U	33	IC DIGITAL MM74C907	5431-7042	12040	MM74C907
U	34	IC DIGITAL MM74C175	5431-7041	12040	MM74C175
U	35	ICD 34011TC 14D Q 2IN NAND DIG	5431-7000	07263	34011TC
U	36	IC DIGITAL SN74LS155N	5431-8755	01295	SN74LS155N
U	37	IC DIGITAL SN74LS155N	5431-8755	01295	SN74LS155N
U	38	ICD SN74174N 16D HX D FLIFLO CLS	5431-8074	01295	SN74174N
U	39	ICD CD4016AE 14D Q BIL SW	5431-7003	86684	CD4016AE
U	40	ICD CD4016AE 14D Q BIL SW	5431-7003	86684	CD4016AE
U	41	ICL CA3130T COS MOS	5432-7000	86684	CA3130T
U	42	IC FET ARRAY	5434-0122	86684	CA3600E
U	43	IC LINEAR LM348N	5432-1055	12040	LM348N
U	44	IC LINEAR LM348N	5432-1055	12040	LM348N
U	45	IC FET ARRAY	5434-0122	86684	CA3600E
U	46	ICL CA3130T COS MOS	5432-7000	86684	CA3130T
Y	1	CRYSTAL PIEZO 24.576MHZ	5075-1201	24655	5075-1201
		NOTE: The part listed above is used only in the 120-Hz version (1657-9700).			
Y	1	CRYSTAL PIEZO 25.06752MHZ	5075-1200	24655	5075-1200
		NOTE: The part listed above is used only in the 100-Hz version (1657-9800).			
Z	1	RESISTOR NETWORK	1657-0800	24655	1657-0800



RANGE NO.	R3	R2
RANGE 1	0	0
RANGE 2	0	1
RANGE 3	1	0

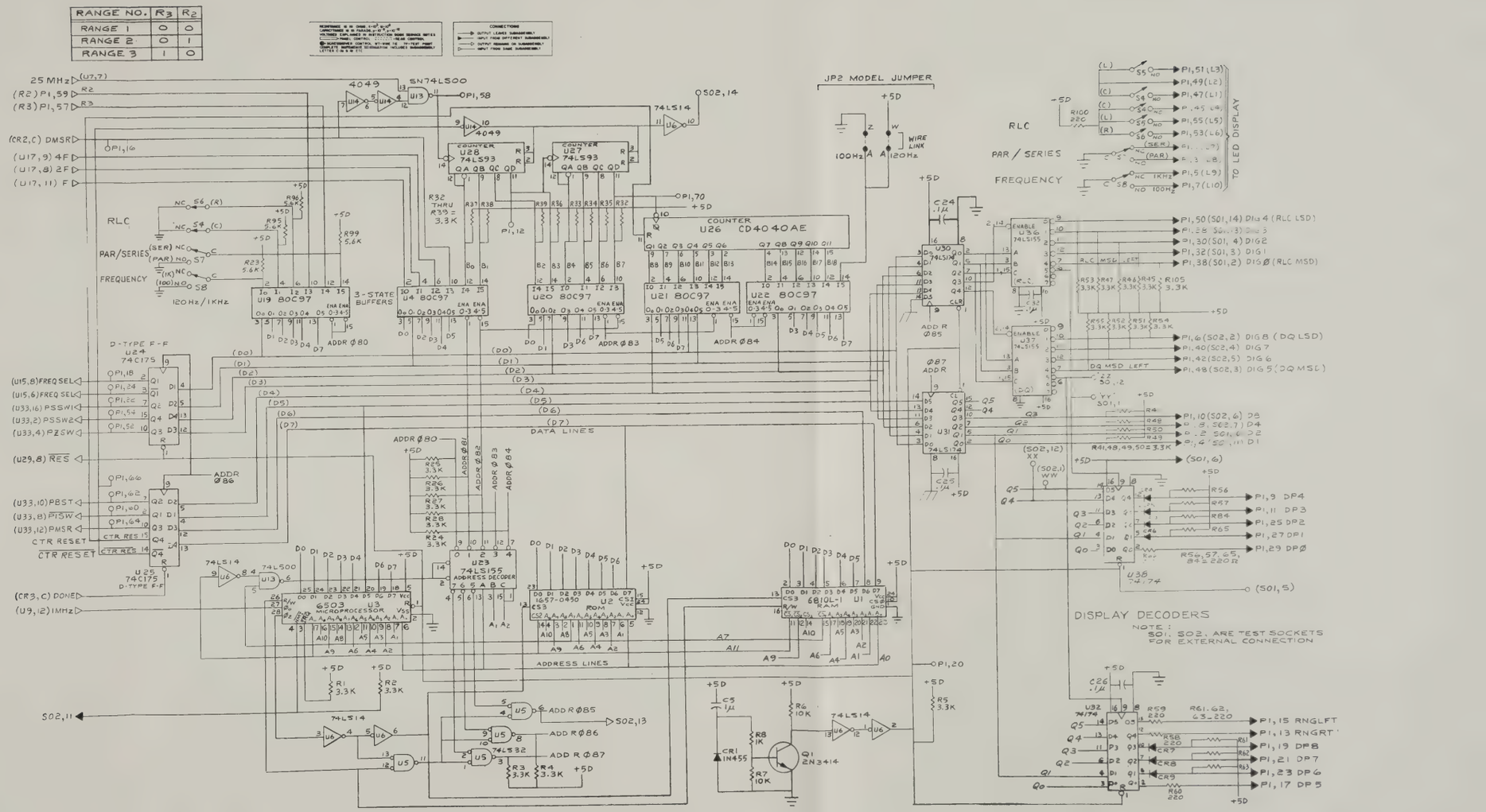
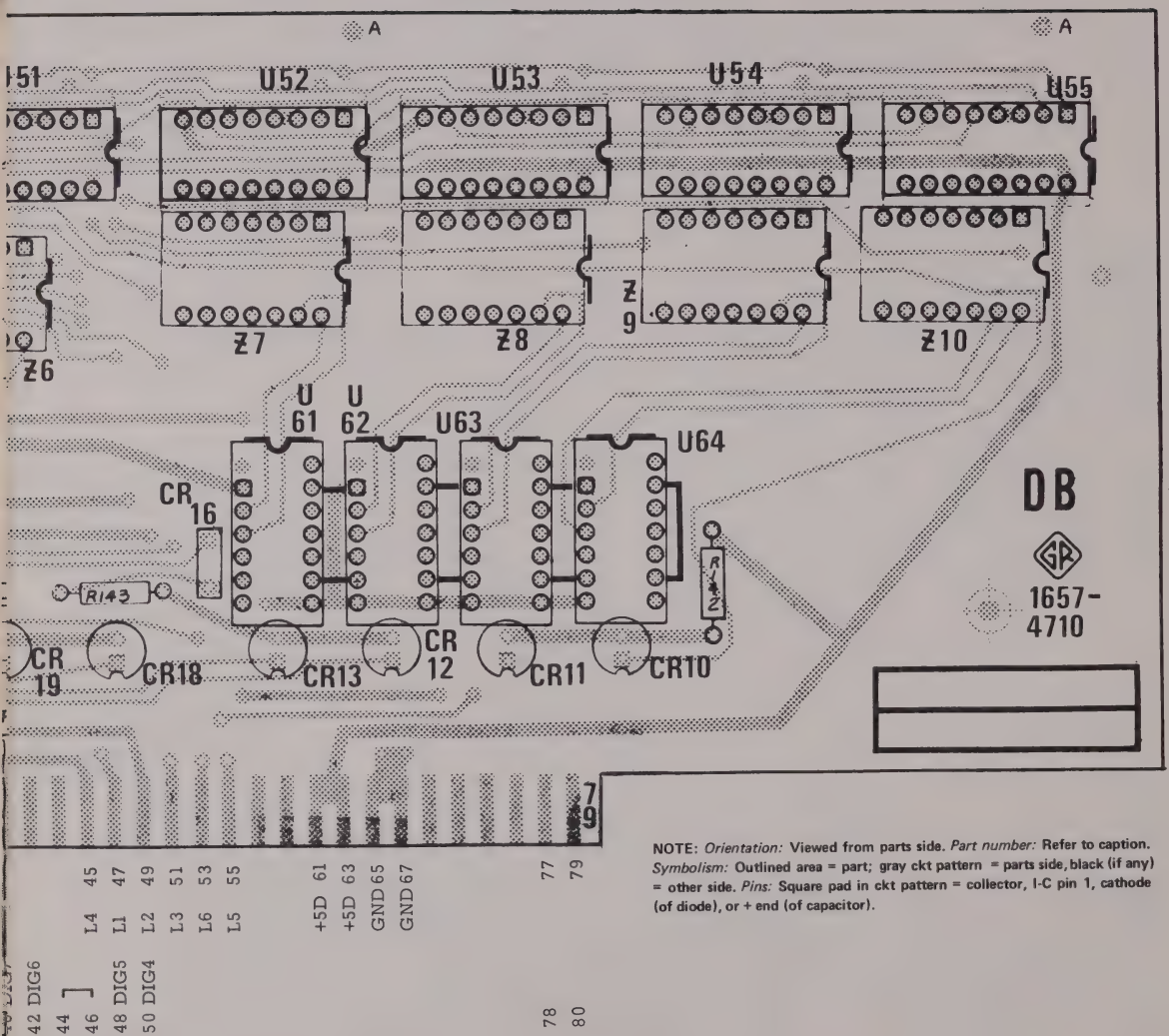


Figure 6-6. Analog and control (C) board, -4700, digital control diagram.



NOTE: *Orientation:* Viewed from parts side. *Part number:* Refer to caption. *Symbolism:* Outlined area = part; gray ckt pattern = parts side, black (if any) = other side. *Pins:* Square pad in ckt pattern = collector, I-C pin 1, cathode (of diode), or + end (of capacitor).

oard, 1657-4710, layout.

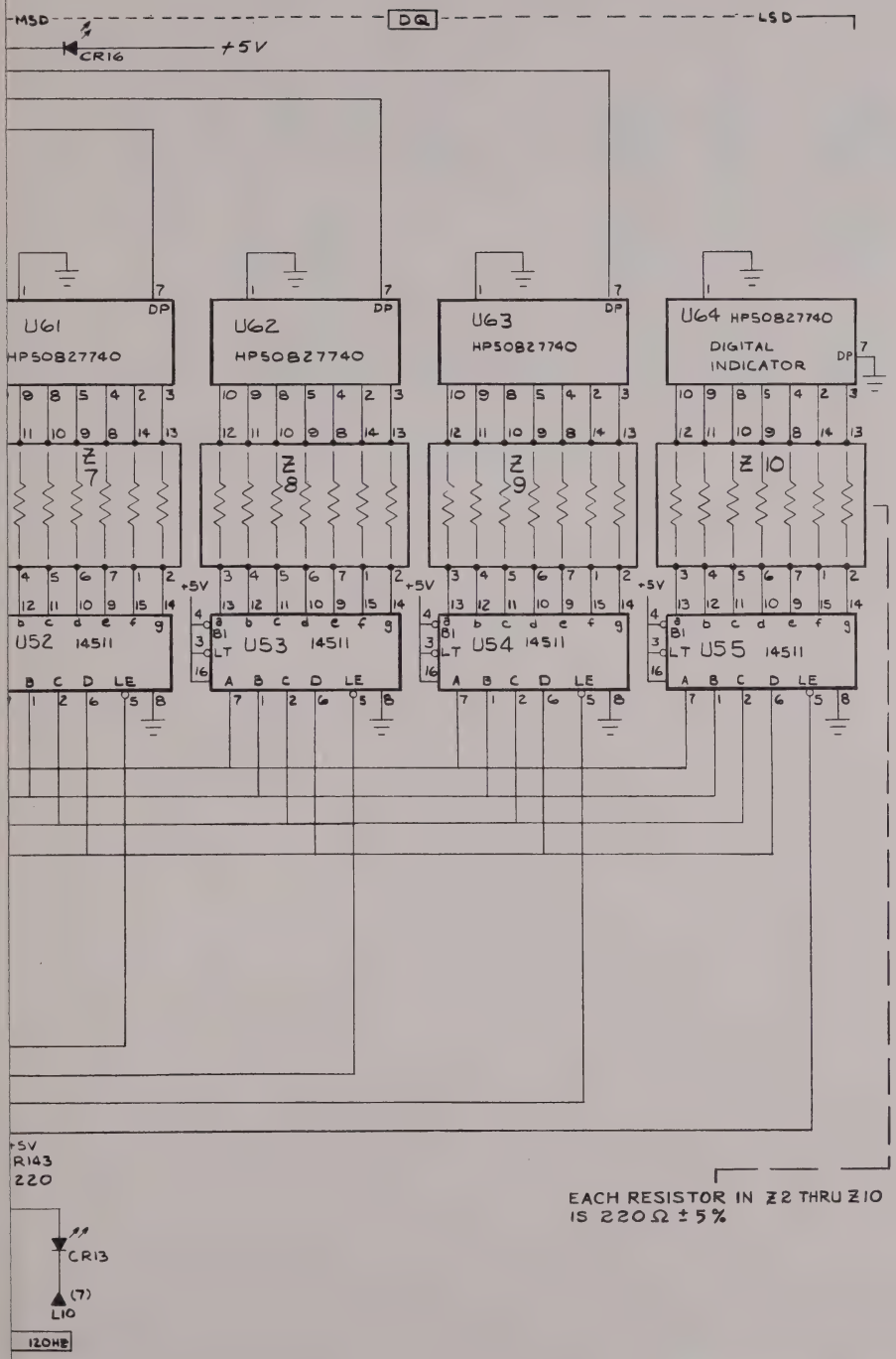
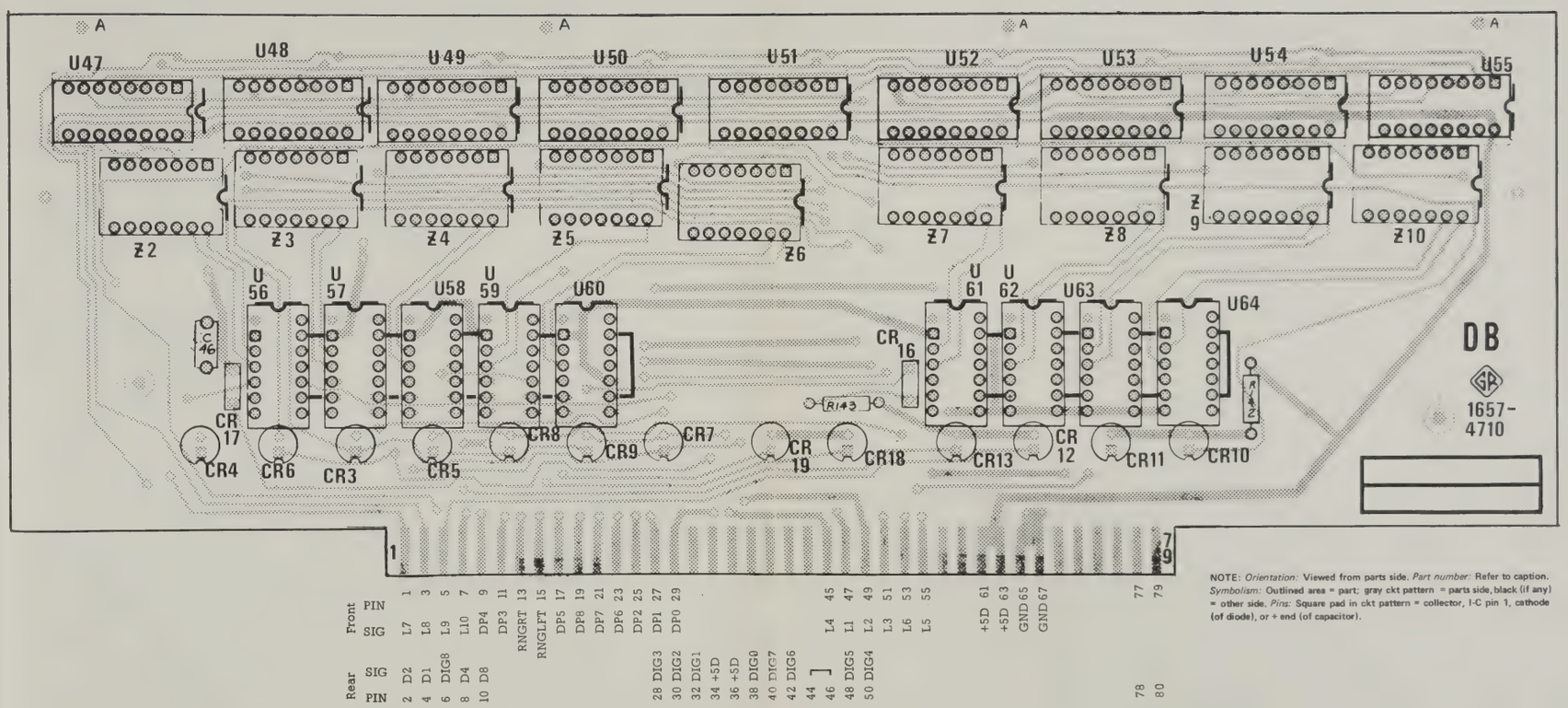


Figure 6-8. Display (D) board, 1657-4710, diagram.

ELECTRICAL PARTS LIST

DISPLAY PC BOARD P/N 1657-4710

REFDES		DESCRIPTION	PART NO.	FMC	MFGR PART NUMBER
C	46	CAP CER MONO 0.1UF 20PCT 50VGP	4400-2050	72982	8131-M050-651-104M
CR	3	LED RED MV5023	6084-1104	71744	CM4-23
CR	4	LED RED MV5023	6084-1104	71744	CM4-23
CR	5	LED RED MV5023	6084-1104	71744	CM4-23
CR	6	LED RED MV5023	6084-1104	71744	CM4-23
CR	7	LED RED MV5023	6084-1104	71744	CM4-23
CR	8	LED RED MV5023	6084-1104	71744	CM4-23
CR	9	LED RED MV5023	6084-1104	71744	CM4-23
CR	10	LED RED MV5023	6084-1104	71744	CM4-23
CR	11	LED RED MV5023	6084-1104	71744	CM4-23
CR	12	LED RED MV5023	6084-1104	71744	CM4-23
CR	13	LED RED MV5023	6084-1104	71744	CM4-23
CR	16	LED RED	6084-1110	72619	555-3007
CR	17	LED RED	6084-1110	72619	555-3007
CR	18	LED RED MV5023	6084-1104	71744	CM4-23
CR	19	LED RED MV5023	6084-1104	71744	CM4-23
R	142	RES COMP 220 OHM 5PCT 1/4W	6099-1225	81349	RCR07G221J
R	143	RES COMP 220 OHM 5PCT 1/4W	6099-1225	81349	RCR07G221J
U	47	MC14511CP 7SEG LAT/DECOD DRVR	5431-7037	04713	MC14511CP
U	48	MC14511CP 7SEG LAT/DECOD DRVR	5431-7037	04713	MC14511CP
U	49	MC14511CP 7SEG LAT/DECOD DRVR	5431-7037	04713	MC14511CP
U	50	MC14511CP 7SEG LAT/DECOD DRVR	5431-7037	04713	MC14511CP
U	51	MC14511CP 7SEG LAT/DECOD DRVR	5431-7037	04713	MC14511CP
U	52	MC14511CP 7SEG LAT/DECOD DRVR	5431-7037	04713	MC14511CP
U	53	MC14511CP 7SEG LAT/DECOD DRVR	5431-7037	04713	MC14511CP
U	54	MC14511CP 7SEG LAT/DECOD DRVR	5431-7037	04713	MC14511CP
U	55	MC14511CP 7SEG LAT/DECOD DRVR	5431-7037	04713	MC14511CP
U	56	INDICATOR DIGITAL .300 CHARACTER	5437-1300	28480	5082-7740
U	57	INDICATOR DIGITAL .300 CHARACTER	5437-1300	28480	5082-7740
U	58	INDICATOR DIGITAL .300 CHARACTER	5437-1300	28480	5082-7740
U	59	INDICATOR DIGITAL .300 CHARACTER	5437-1300	28480	5082-7740
U	60	INDICATOR DIGITAL .300 CHARACTER	5437-1300	28480	5082-7740
U	61	INDICATOR DIGITAL .300 CHARACTER	5437-1300	28480	5082-7740
U	62	INDICATOR DIGITAL .300 CHARACTER	5437-1300	28480	5082-7740
U	63	INDICATOR DIGITAL .300 CHARACTER	5437-1300	28480	5082-7740
U	64	INDICATOR DIGITAL .300 CHARACTER	5437-1300	28480	5082-7740



NOTE: *Orientation:* Viewed from parts side. *Part number:* Refer to caption. *Symbolism:* Outlined area = part; gray ckt pattern = parts side, black (if any) = other side. *Pins:* Square pad in ckt pattern = collector, I-C pin 1, cathode (of diode), or + end (of capacitor).

Figure 6-7. Display (D) board, 1657-4710, layout.

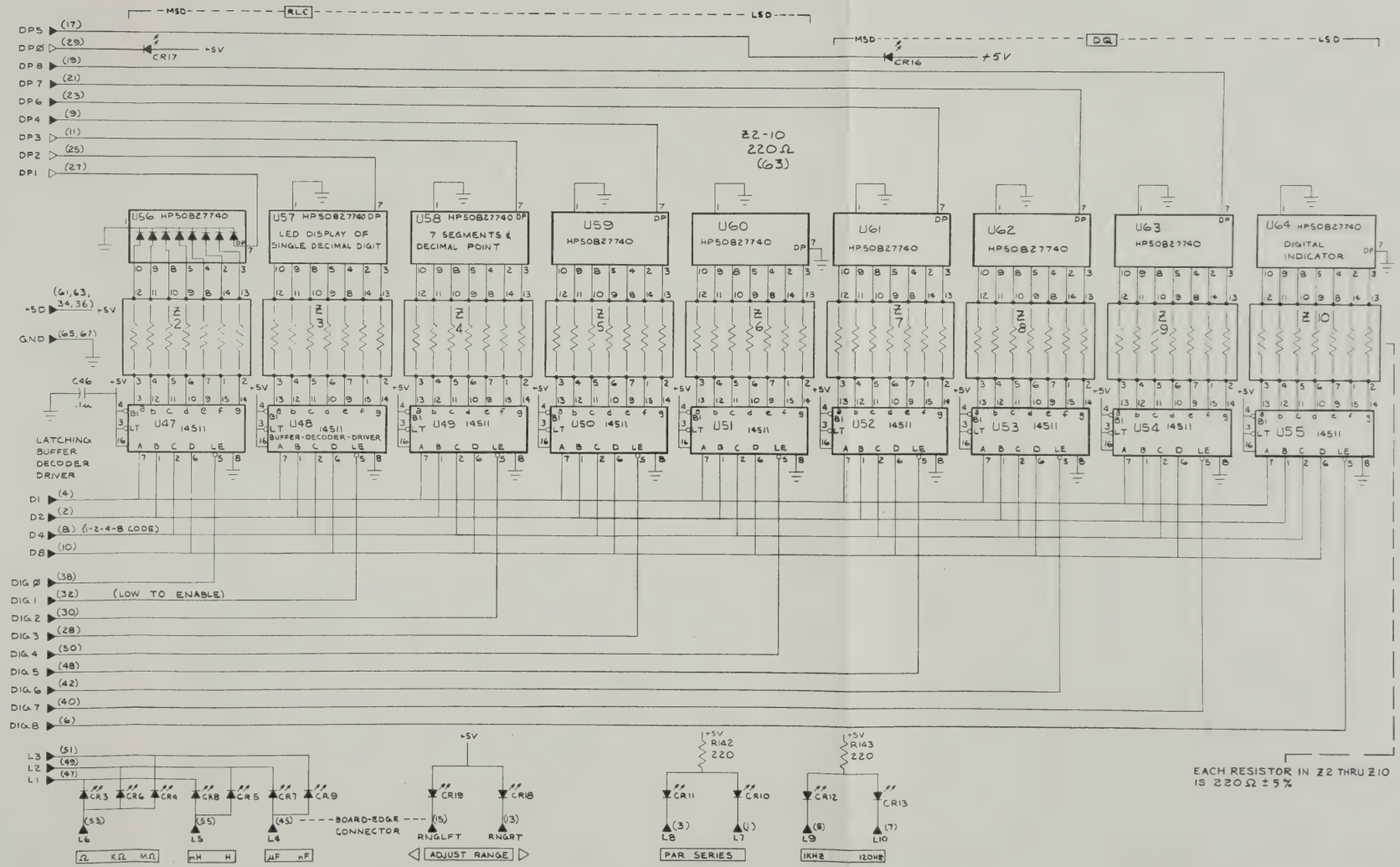


Figure 6-8. Display (D) board, 1657-4710, diagram.

ELECTRICAL PARTS LIST

POWER SUPPLY PC BOARD P/N 1657-4720

REFDES		DESCRIPTION	PART NO.	FMC	MFGR PART NUMBER
C	3	CAP TANT 1.0 UF 20PCT 35V	4450-4300	56289	150D105X0035A2
C	4	CAP TANT 1.0 UF 20PCT 35V	4450-4300	56289	150D105X0035A2
C	7	CAP TANT 1.0 UF 20PCT 35V	4450-4300	56289	150D105X0035A2
C	8	CAP CER MONO .01 UF 10PCT 50V	4400-6351	72982	8121-M050-W5R-103K
C	9	CAP CER MONO .01 UF 10PCT 50V	4400-6351	72982	8121-M050-W5R-103K
C	10	CAP CER MONO .01 UF 10PCT 50V	4400-6351	72982	8121-M050-W5R-103K
C	11	CAP TANT 1.0 UF 20PCT 35V	4450-4300	56289	150D105X0035A2
CR	5	DIODE RECTIFIER 1N4003	6081-1001	14433	1N4003
CR	6	DIODE RECTIFIER 1N4003	6081-1001	14433	1N4003
CR	7	DIODE RECTIFIER 1N4003	6081-1001	14433	1N4003
CR	8	DIODE RECTIFIER 1N4003	6081-1001	14433	1N4003
CR	9	RECT 1N4140 100PIV 3A SI A1XM	6081-1014	14433	1N4140
CR	10	RECT 1N4140 100PIV 3A SI A1XM	6081-1014	14433	1N4140
S	1	SWITCH PUSHBUTTON PWR LINE	7870-1567	24655	7870-1567
U	2	IC LINEAR LM342P-5	5432-1058	12040	LM342P-5
U	3	IC LINEAR LM320MP-8	5432-1059	12040	LM320MP-8

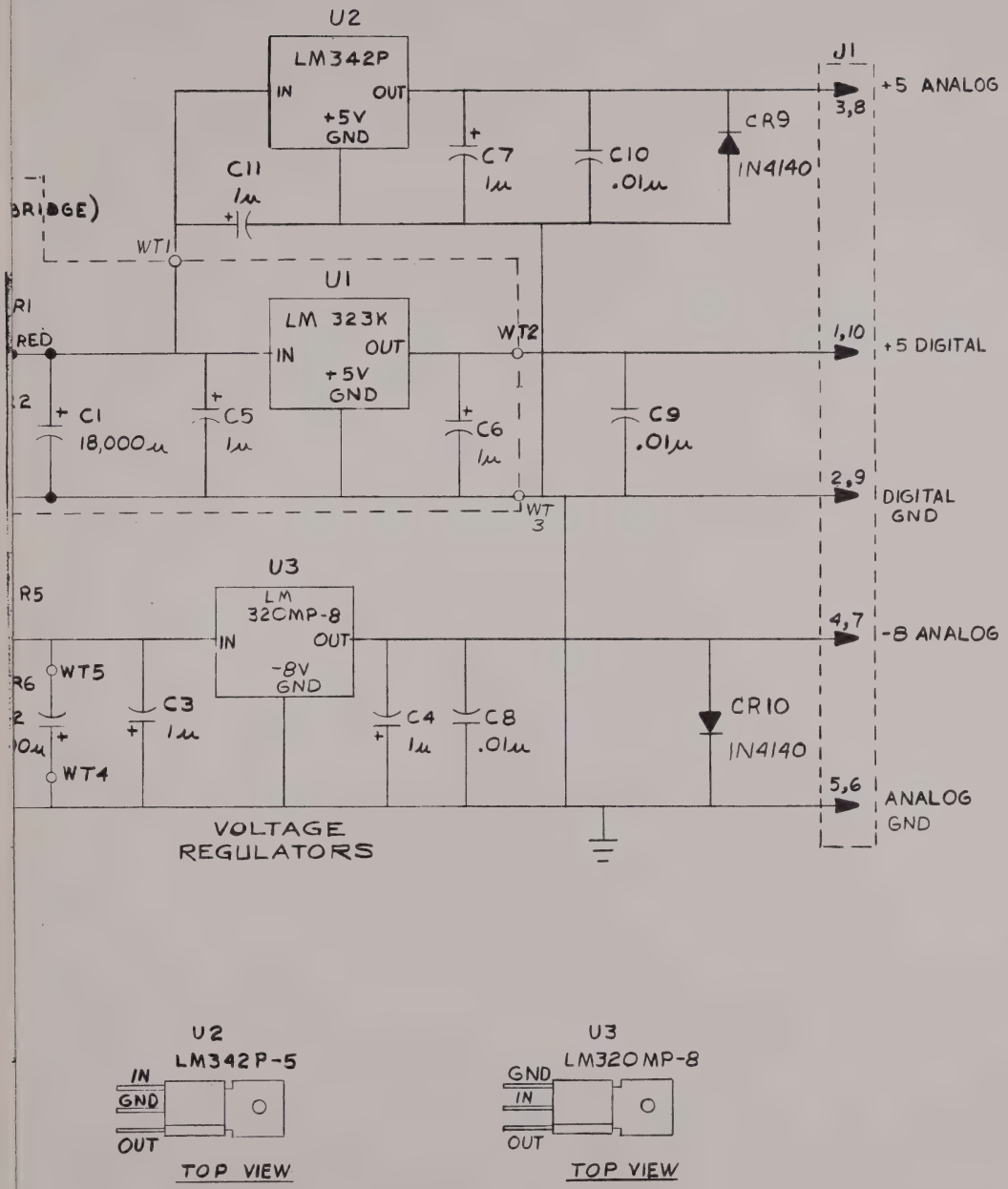


Figure 6-10. Power supply (V) assembly, 1657-4000, diagram.

ELECTRICAL PARTS LIST

POWER SUPPLY ASM P/N 1657-4000

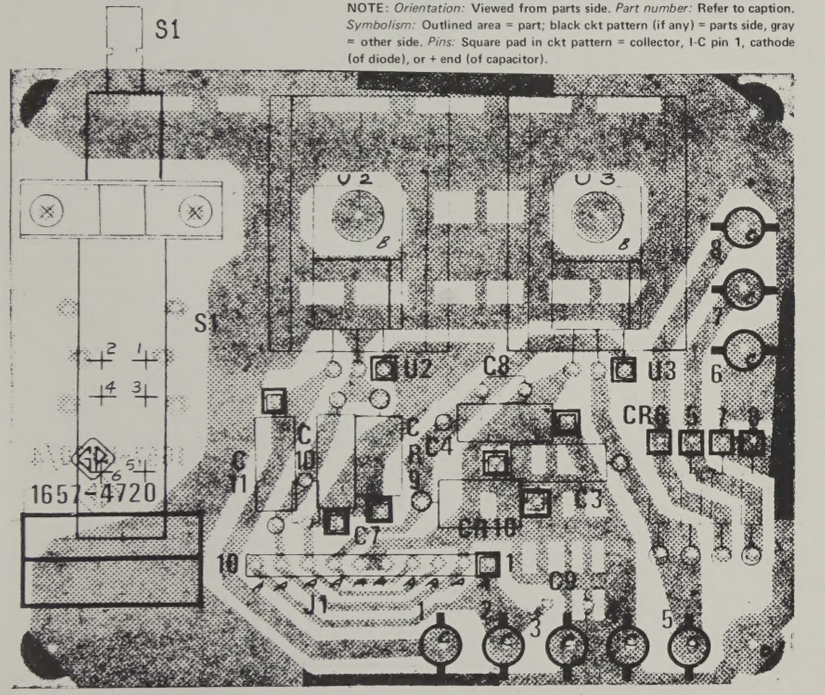
REFDES		DESCRIPTION	PART NO.	FMC	MFGR PART NUMBER
C	1	CAP ALUM 18000 UF 20V	4450-6231	24655	4450-6231
C	2	CAP ALUM 4500 UF 40V	4450-6221	90201	CGS 4500UF 40V
C	5	CAP TANT 1.0 UF 20PCT 35V	4450-4300	56289	150D105X0035A2
C	5	CAP TANT 1.0 UF 20PCT 35V	4450-4300	56289	150D105X0035A2
C	6	CAP TANT 1.0 UF 20PCT 35V	4450-4300	56289	150D105X0035A2
C	6	CAP TANT 1.0 UF 20PCT 35V	4450-4300	56289	150D105X0035A2
CR	1	DIODE BRIDGE	6081-1032	24655	6081-1032
CR	2	DIODE BRIDGE	6081-1032	24655	6081-1032
CR	3	DIODE BRIDGE	6081-1032	24655	6081-1032
CR	4	DIODE BRIDGE	6081-1032	24655	6081-1032
F	1	FUSE SLO-BLOW 1/2A 250V	5330-1000	75915	313 .500
J	101	RECEPTACLE POWER IEC STD 6A 250V	4240-0210	24655	4240-0210
S	2	SWITCH SLIDE 2 POS DPDT STEADY	7910-0832	82389	11A-1266
U	1	IC LINEAR LM323	5432-1048	12040	LM323K

NOTE: THIS ASSEMBLY INCLUDES THE CIRCUIT BOARD - - - - - - - 1657-4720

ELECTRICAL PARTS LIST

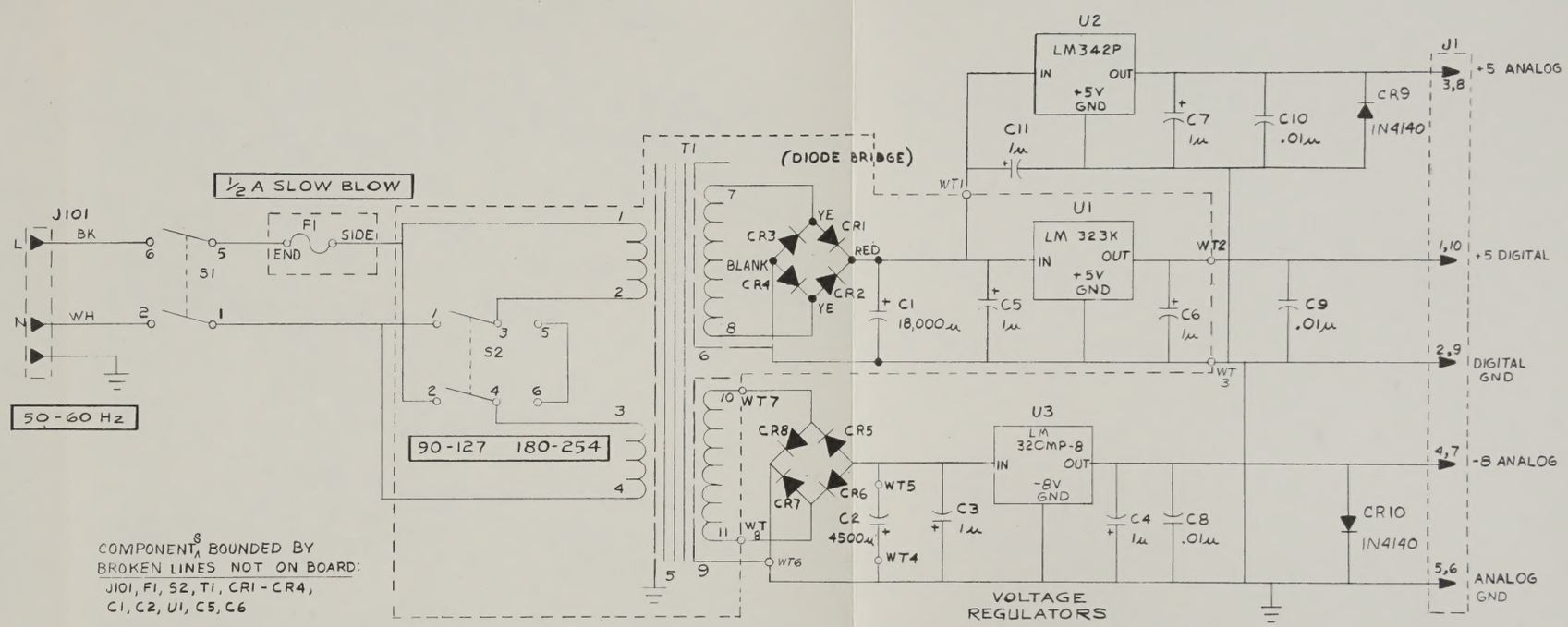
POWER SUPPLY PC BOARD P/N 1657-4720

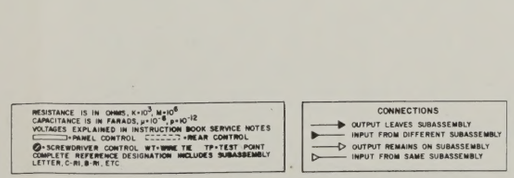
REFDES		DESCRIPTION	PART NO.	FMC	MFGR PART NUMBER
C	3	CAP TANT 1.0 UF 20PCT 35V	4450-4300	56289	150D105X0035A2
C	4	CAP TANT 1.0 UF 20PCT 35V	4450-4300	56289	150D105X0035A2
C	7	CAP TANT 1.0 UF 20PCT 35V	4450-4300	56289	150D105X0035A2
C	8	CAP CER MONO .01 UF 10PCT 50V	4400-6351	72982	8121-M050-W5R-103K
C	9	CAP CER MONO .01 UF 10PCT 50V	4400-6351	72982	8121-M050-W5R-103K
C	10	CAP CER MONO .01 UF 10PCT 50V	4400-6351	72982	8121-M050-W5R-103K
C	11	CAP TANT 1.0 UF 20PCT 35V	4450-4300	56289	150D105X0035A2
CR	5	DIODE RECTIFIER 1N4003	6081-1001	14433	1N4003
CR	6	DIODE RECTIFIER 1N4003	6081-1001	14433	1N4003
CR	7	DIODE RECTIFIER 1N4003	6081-1001	14433	1N4003
CR	8	DIODE RECTIFIER 1N4003	6081-1001	14433	1N4003
CR	9	RECT 1N4140 100PIV 3A SI A1XM	6081-1014	14433	1N4140
CR	10	RECT 1N4140 100PIV 3A SI A1XM	6081-1014	14433	1N4140
S	1	SWITCH PUSHBUTTON PWR LINE	7870-1567	24655	7870-1567
U	2	IC LINEAR LM342P-5	5432-1058	12040	LM342P-5
U	3	IC LINEAR LM320MP-8	5432-1059	12040	LM320MP-8

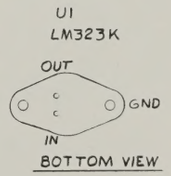


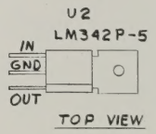
NOTE: *Orientation:* Viewed from parts side. *Part number:* Refer to caption. *Symbolism:* Outlined area = part; black ckt pattern (if any) = parts side, gray = other side. *Pins:* Square pad in ckt pattern = collector, I-C pin 1, cathode (of diode), or + end (of capacitor).

Figure 6-9. Power supply (V) board, 1657-4720, layout.




RESISTANCE IS IN OHMS, K=10³, M=10⁶
CAPACITANCE IS IN FARADS, µ=10⁻⁶, p=10⁻¹²
VOLTAGES EXPLAINED IN INSTRUCTION BOOK SERVICE NOTES
=PANEL CONTROL =REAR CONTROL
=SCREWDRIVER CONTROL WT=WIRE TIE TP=TEST POINT
COMPLETE REFERENCE DESIGNATION INCLUDES SUBASSEMBLY LETTER, C-A1, B-A1, ETC
CONNECTIONS
OUTPUT LEAVES SUBASSEMBLY
INPUT FROM DIFFERENT SUBASSEMBLY
OUTPUT REMAINS ON SUBASSEMBLY
INPUT FROM SAME SUBASSEMBLY





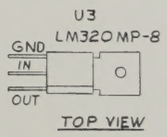


Figure 6-10. Power supply (V) assembly, 1657-4000, diagram.

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